HERCULES POWDER COMPANY
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15 July 1966

IN REPLY REFER TO: 544/10/9-513

487916

Headquarters
Ballistic Systems Division
Air Force Systems Command
Norton Air Force Base
San Bernardino, California

Attention: BSRPQ-1 - Capt. W. R. Cosgrove

Subject: Motor Storage Studies Program Plan, Report No. MTO-258-3A, Revision 2, Change 1, Volumes I and II, Dated 1 July 1966

References: (1) Contract AF 04(694)-544, Exhibit "A", Part VII, Paragraph C, as amended by CCN 50

(2) BSD TWX, BSRKP-3/32695, June 1966

(3) Igniter Failure Criteria Study, Letter 544/5/15-801, Dated 19 April 1966

Gentlemen:

In accordance with Reference (1), and in response to Reference (2), one copy of the subject document change pages is hereby submitted. The change pages incorporate the BSD Approval TWX, Reference (2), comments into the Motor Storage Studies Program Plan, MTO 258-3A, Revision 2, dated 15 January 1966.

Since Change 1 of the subject document does impact the contract, especially in the area of incorporating the Igniter Failure Criteria Study, which includes procurement of 17 Pyrogen Igniters and associated testing as defined in Reference (3), it is requested that action be initiated to incorporate the subject change into the contract.

Very truly yours,

for D. E. Thompson
M. W. PLUNKETT, MANAGER
MINUTEMAN PROGRAM

MWP:AFeurer:vib

HERCULES

9 Technical Operating ~~Report~~.
[redacted]

14 MTO-258-3A-VoL-1-Rev-2,
MTO-258-3A-VoL-2-Rev-2

6 MOTOR STORAGE STUDIES PROGRAM PLAN.

~~MTO-258-3A, REVISION 2~~

WEAPON SYSTEMS 133A AND B. Volumes I. and II.

11 ~~15 January 1966~~
[redacted] 1 Jul[redacted]66 12 272p.

[redacted]

[redacted] 15 AF 04(694)-544

LATEST CHANGED PAGES SUPERSEDE
THE SAME PAGES OF PREVIOUS DATE

CHANGE NOTICE

Insert changed pages. Destroy superseded pages.

Prepared by

HERCULES INCORPORATED
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
Norton Air Force Base
California

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LIST OF EFFECTIVE PAGES (Volume I) 1 July 1966

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*1-10A thru 1-10F Added	1 Jul 66	*2-66	1 Jul 66
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*2-3	1 Jul 66	2-109	Original
2-4	Original	*2-110	1 Jul 66
*2-5 thru 2-7	1 Jul 66	2-111 thru 2-115	Original
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*2-38 thru 2-43	1 Jul 66	2-171 and 2-172	Original
2-44	Original	*2-173 and 2-174	1 Jul 66
*2-45 thru 2-47	1 Jul 66	*2-175 thru 2-180 Added	1 Jul 66

Report No. MTO-258-3A, Rev 2, Change 1

Copy No. 4

Date 1 July 1966

MOTOR STORAGE STUDIES PROGRAM PLAN
WEAPON SYSTEMS 133A AND B

Volume I

Reviewed by

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FOREWORD

This document presents the Motor Storage Studies Program Plan and the Hercules plan for development of failure criteria.

The original authority and requirements for motor storage studies were established in Contract AF 04(647)-243, Exhibit B, paragraph III.F.5, and Exhibit D, Section III, paragraph D.9; and as amended by CCN's No. 108, 165, and 200.

Authority for continuation of the motor storage program from 1 July 1963 thru 30 June 1965 is given in Contract AF 04(694)-127, Exhibit A, paragraph D.9, as amended by CCN's 201, 208, and 269.

Authority for continuation of the motor storage program from 1 July 1965 thru 30 September 1966 is given in Contract AF 04(694)-544, Exhibit A, part VII, paragraph C, as amended by CCN No. 50.

This document supersedes MTO-258-3A, Revision 1, Motor Storage Studies Program Plan, dated 1 December 1964, and is presented in two volumes. Volume I contains the effort which was transferred from Air Force Systems Command (AFSC) to Air Force Logistics Command (AFLC) in the transfer of engineering responsibility of Wing I thru Wing V. Each test schedule indicates the effort remaining as of transfer date, 1 October 1966. Volume II contains the effort which is the responsibility of Air Force Systems Command (full-scale unit effort and materials unique to Operational Reliability Improvement (OPRI)).

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Magna, Utah

ABSTRACT

The Minuteman stage III motor storage studies are comprised of three major tasks: Motor Storage, Laboratory Support, and Failure Criteria Development. The program plan since initiation in 1958 has been continually updated for AFBSD. In December 1965 Hercules received contractual coverage to divide the program plan into two volumes, one volume to contain the effort for which the engineering responsibility is to be transferred from AFSC to AFLC (Wings I through V motors and components), and the other volume to contain the effort for which the engineering responsiblity will remain with AFSC after 1 July 1966.

1. Volume I

Volume I of this document contains the history of the overall program and the effort required after transfer of engineering responsibilities to AFLC. This volume contains the AFLC portion of the storage program plan, including the areas described in the following paragraphs.

Wings I through V motor storage is primarily designed to demonstrate storage capabilities of the Minuteman stage III rocket motor. To accomplish this, a total of 27 full-scale motors (15 Wing I R & D, 2 Wing I operational, 6 Wing II operational, and 4 Wing IV operational) were placed in storage under simulated operational environments, conditioned, inspected, and static tested after aging periods from 1 to 10 yr.

The Laboratory Support Program (Wings I through V component and material testing) is designed to predict the service life of the individual components and materials and ultimately the service life of the stage III motors. The study involves storing, conditioning, and testing components and materials used in the stage III motors, independent of the motors. These components and materials are stored under environments representing the common and extremes of the Minuteman Model Specification. Resultant test data are analyzed and compared to previous test results to establish the aging trends used for service life prediction as reported quarterly.

The Failure Criteria Development Program has been added to the original scope of the program to provide failure criteria for items tested in the Laboratory Support Program. This criteria is essential for making accurate and meaningful service life predictions.

2. Volume II

Volume II of this document contains the effort for which AFBSD will retain the engineering responsibility after 1 July 1966. This effort contains two Wing VI full-scale motors and Wing VI unique materials and components. The storage conditioning and testing of these items is performed in a similar manner to those items being tested in Volume 1.

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SECTION II

TASK REQUIREMENTS

The tasks set forth below represent Hercules' interpretation of the Motor Storage Studies Program Plan requirements stated in the work statement for Contract AF 04(694)-544, Exhibit A, part VII, paragraph C and incorporated CCN's. The tasks are:

(1) Prepare and submit for BSD approval, and maintain in current status, the Motor Storage Studies Program Plan (The program plan shall be published in looseleaf form and shall reflect the actual work in progress as well as work planned.)

(2) Continue the Motor Storage Studies Program, as described in this document

(3) Develop failure criteria which can be used in conjunction with results from the Laboratory Support Program to predict the service life of the materials and subsystems which makeup the Minuteman stage III motor

(4) Perform preliminary failure analysis investigation on anomalies observed during the testing, inspections, or observations directed by this program plan (The preliminary investigation shall be sufficiently detailed to define the problem, make a reasonable estimate whether aging is involved, and plan a comprehensive investigation program in situations in which BSD concurs and where aging is a factor. The implementation of a comprehensive investigation shall be subject to separate contractual action. Reports concerning the investigation will be issued as part of the Surveillance Quarterly Report.)

(5) Participate in the Hill Air Force Base (HAFB) cooperative propellant test program

(6) Support Surveillance Working Group (SWG) meetings

(7) Evaluate and, where applicable, combine the results of the Ogden Air Materiel Area (OOAMA) storage program with those obtained from the Hercules' conducted R & D storage program to improve the accuracy of service life predictions and demonstrations

(8) Assist OOAMA in analysis of the first five Minuteman stage III motor firings to be conducted at the Lakeside Test Facilities (FTM spare 4, SD-22, 1A3, 1A7, and one undesignated motor to be tested prior to 1 October 1966)

(9) Upon request from BSD, furnish copies of any published procedure or specification used in any phase of the work described by this document

SECTION III

PLAN FOR ACCOMPLISHING TASKS

A. PREPARATION AND MAINTENANCE OF THE MOTOR STORAGE STUDIES PROGRAM PLAN

This document has been prepared to describe the effort and respective responsibilities of AFLC and AFSC beginning 1 October 1966. AFLC effort is outlined in Volume I, and the AFSC effort is shown in Volume II.

The submittal of this document partially meets the requirements of preparing and maintaining the Motor Storage Studies Program Plan. The remaining requirement to maintain the program plan in current status will be accomplished by submitting change pages.

The program plan will be updated as required. Changes affecting program planning must be approved by the Program Contracting Officer.

B. STORAGE PROGRAM CONTINUATION

1. Overall Storage Program Objectives

The overall objectives of Hercules Motor Storage (Aging) Program are to evaluate the storage capabilities of the stage III Minuteman rocket motor under environmental conditions representative of the operational concept and, ultimately, aid in the prediction of the usable life of the operationally deployed motors. Specific objectives of the program are to:

(a) Provide the information required for predicting motor maintenance and replacement factors

(b) Demonstrate the operational storage capabilities of the Minuteman stage III motors

(c) Determine the factors which limit the service life of the motors

2. Orientation

The Hercules Motor Storage Program is divided into two parts: Motor Storage and Laboratory Support. An additional surveillance effort, designated as the extension program, has been incorporated. The new program is designed to extend the original surveillance testing to 10 years.

The AFSC effort consists of the Wing VI full scale unit Motor Storage Program and the materials studied in the Operational Reliability Improvement (OPRI) Program. The testing and procedural details of these programs are given in Volume II of this document.

The AFLC effort consists of the Wings I through V materials and components and the Failure Criteria Studies. The testing and procedural details for this effort are given in Volume I of this document. The appendixes contain completed or discontinued test plans, the FSU grain dissection procedure, storage motor inspection records, and the program special tooling requirements.

The basic plan for implementing the storage program is given in the following paragraphs. A summary of tasks completed is given in Chapter 1, Section IV, of this document.

3. Motor Storage

The motor storage effort consists of storing, conditioning, periodically inspecting, and testing 17 Wing I, 6 Wing II, 4 Wing IV, and 2 Wing VI stage III Minuteman rocket motors. The 17 Wing I motors include the 2 stage III motors returned from Hill Air Force Base (HAFB) in January 1965 from missiles 501 and 511. These two motors, assigned to the program as test numbers 1-5-21 and 1-5-22, are from the first Wing I operational motors produced by Hercules. The motors are stored at HAFB in Hercules' assigned buildings for various storage periods under environmental conditions simulating the hardened and dispersed conditions for the WS-133A Operational Weapon System. The detailed test plan for inspection, storage, testing, and data reduction is given in Chapter 3, Section I. A brief description of the storage, conditioning, and testing is given in the following subparagraphs.

a. Storage

The subject motors were produced by Hercules Powder Company, Bacchus Works (HPC/B), and designated as storage motors.

The Wing I motors were selected and assigned to the program prior to completion of production and were transported to the 1800 area at HAFB for storage. When the motors were recalled to HPC/B for igniter retrofit, simulated hardware was installed to subject the motors to loads that could be expected in operationally deployed missiles.

The Wing II motors were shipped to Plant 77, assembled into the missiles, and placed in the field for approximately 1 year. When replacement motors became available, the stage III motors were removed from the missiles on a normal recycle to OOAMA and assigned to the storage program. The motors were transported to HPC/B for complete inspections, and simulated hardware was installed prior to returning the motors to the 1800 area at HAFB for storage.

The Wing IV motors were assigned to the Storage Program immediately after production completion, simulated hardware was installed, and the motors were shipped to the 1800 area at HAFB for storage. These motors were selected from the first 24 motors manufactured.

The Wing VI motors (AFSC responsibility) were assigned to the Storage Program prior to production. These motors will be transported to the 1800 area at HAFB for storage and returned to HPC/B for installation of simulated NCU's when this equipment is available.

Two Wing I motors were added to the storage program as the result of assigning missiles 501 and 511 to OOAMA for disassembly and shakedown testing at the Lakeside Test Facilities. Motors from the two missiles were replaced by motors SD-22 and FTM Spare 4. These motors will be used to test the new firing stands and data acquisition system at the Lakeside Test Facilities. Motors assigned to the storage program, ETP No. 1 and ETP No. 3, were returned to HPC/B, complete inspection was performed, necessary rework was accomplished, and the simulated hardware was installed. The two motors were then transported to the 1800 area at HAFB for storage.

The motors were placed in temperature and humidity-controlled storage bays in vertical or horizontal positions. An initial visual inspection for defects was made and repeated every 2 months during storage. A log is kept of all inspection results.

b. Conditioning

Each motor is inspected thoroughly after its scheduled storage to determine and document any changes resulting from storage. The motor is then subjected to transportation conditioning by means of an electro-mechanical vibrator.

c. Testing

The motor is reinspected to determine and document any changes resulting from the transportation conditioning, and a Firing Test Plan is issued. The motor is instrumented, test fired, and given a post-firing inspection to determine and document any aging effects revealed by the firing. The Wing I R & D and operational surveillance motor firing schedule is shown in Table 1-1. The Motor Storage Studies Program motor firing schedule is given in Volume II, Table 3-3.

d. Reporting

Reports are submitted after the firing. All data generated during the life of the individual motor, including final firing data, are analyzed and interpreted to establish aging characteristics and storage capabilities of motors in the operational environment.

4. Laboratory Support

The laboratory support effort supports the Motor Storage Program by providing data on components and subassemblies stored independently of the motor under conditions which simulate common and extreme operational environments. Separate testing of components offers the accumulation of

TABLE 1-1

WING I R & D AND OPERATIONAL SURVEILLANCE MOTOR FIRING SCHEDULE

Motor No.	Type	Scheduled Storage Period	Scheduled Testing Date
243B-1-5-20*	R & D	11	Dec 61
243B-1-5-1*	R & D	16	Mar 62
243B-1-5-4*	R & D	18	Jun 62
243B-1-5-5*	R & D	19	Oct 62
243B-1-5-3*	R & D	25	Jan 63
243B-1-5-6*	R & D	28	Aug 63
243B-1-5-10*	R & D	30	Apr 63
243B-1-5-8*	R & D	36	Jun 64
243B-1-5-2*	R & D	49	Dec 64
Oper 1	Operational	45	Sep 65
243-B-1-5-9	R & D	53	Mar 66
Oper 2	Operational	48	Jan 66
Oper 3	Operational	55	Jul 66
XS-1	Operational	55	Jul 66
XS-2	Operational	56	Aug 66
243-B-1-5-12	R & D	59	Aug 66
XS-3	Operational	57	Sep 66
XS-4	Operational	58	Nov 66
Oper 4	Operational	60	Jan 67
XS-5	Operational	61	Feb 67
XS-6	Operational	62	Mar 67
Oper 5	Operational	66	Jul 67
XS-7	Operational	66	Jul 67
243-B-1-5-7	R & D	67	Dec 66
XS-8	Operational	67	Aug 67
XS-9	Operational	68	Sep 67
XS-10	Operational	69	Oct 67
XS-11	Operational	69	Oct 67
243-B-1-5-21	R & D	71	Nov 67
XS-12	Operational	71	Dec 67
Oper 6	Operational	72	Jan 68
XS-13	Operational	73	Feb 68
XS-14	Operational	74	Mar 68
XS-15	Operational	75	Apr 68
243-B-1-5-22	R & D	76	May 68
XS-16	Operational	77	Jun 68
XS-17	Operational	77	Jun 68
XS-18	Operational	78	Jul 68
Oper 7	Operational	79	Aug 68
XS-19	Operational	80	Sep 68
XS-20	Operational	81	Oct 68
243-B-1-5-14	R & D	81	Nov 68
XS-21	Operational	82	Nov 68
XS-22	Operational	85	Feb 69
XS-23	Operational	86	Mar 69
XS-24	Operational	87	Apr 69
243-B-1-5-15	R & D	88	Jul 69
243-B-1-5-11	R & D	96	Apr 70

*Fired by Hercules at Bacchus

data not available from study of the complete motor due to inaccessibility of many components and the comparatively narrow scope of testing environments. The program uses a comprehensive variety of operational environments in order to isolate individual environmental effects and to identify conditions which might reduce the usable life of the deployed motor with time. Component service life values are predicted by extrapolating trends observed in component data. These predictions are an estimate of the time a component can be stored and still perform the function for which it was designed. The motor assumes the service life of the non-replaceable weak link component.

Subassemblies and components subjected to storage, inspection, conditioning, and testing are described by a series of individual studies. These studies presented in Chapter 2, Sections I through XIII, are:

(a) Igniter

(b) Igniter pellets

(c) Thrust terminator arm-disarm switch

(d) Nozzles

(e) Propellant

(f) Case bond system

(g) Spiralloy case

(h) Frangible sectors

(i) Internal insulation

(j) Pressure seals

(k) External insulation

(l) Adhesives and potting materials

Similarity of Wings I through VI motor configurations has allowed certain Wing I laboratory data to be equally adaptable to other wings. To simplify the program and to reduce material and manpower costs, these data have been used whenever possible.

Items rejected by Hercules' Receiving Quality Control (RQC) which will provide sufficiently accurate data was used whenever possible.

5. Laboratory Support Extension

The initial planning for the Laboratory Support Program called for 3-year testing of Wing I components and 5-year testing of Wings II through VI components. This initial planning was based on the respective 3- and 5-year motor life criteria, established during the R & D Program for Wing I and Wings II through VI configuration. Since the time of initial planning, motor target life has been extended to 7 years for Wing I configuration and 10 years for Wings II through VI configuration.

The Laboratory Support Extension Program was designed to update the component storage program to conform with the most recent planning and to provide data which can be used to more accurately predict service life values by means of improved failure criteria. Table 1-1A details schedule of tests from the beginning of the program as it was originally planned to the completion of the program, including tests added as a result of the extension. Additional wing coverage provided by the laboratory extension program and the lead time gained or lost by adding items, after originally establishing the program, are shown in Table 1-2.

Samples to extend the program were acquired from FSU motors or aged excessed materials, or procured new from the vendor. Rubber, phenolic, propellant, and case-bond system samples are obtained by dissection of aged FSU motors. There are five Wing I and one Wing II motors scheduled for dissection as shown in Table 1-3. Detailed cutting procedures are given in Appendix B. Table 1-4 lists basic configuration of each motor selected for dissection.

6. <u>Analysis of Data</u>

a. <u>Motor Storage</u>

The data obtained from the periodic motor inspections during storage at HAFB will be evaluated for each motor prior to static firing. The purpose of the evaluation is to determine the areas which have experienced degradation and which will require monitoring during static firing. Data developed from the Wing I storage motor static firing will be compared to PFRT data. Wing II, Wing IV, and Wing VI motor static firing data, and postfiring inspection results will be compared to data recorded on Wing II, Wing IV, and Wing VI qualification motors to determine degradation of the measured parameters of the aged motor.

b. <u>Laboratory Support</u>

Data generated from the Laboratory Support Program is used primarily to predict service life of subsystems and components. It can also be used as an aid in performing failure analysis. (The term failure analysis, as used in this document, is defined as the process of investigating an anomalous performance to determine the cause and the required corrective action.)

The approach to be used for conducting failure analysis on surveillance items is delineated in paragraph D.

Table 1-5 lists major parameters measured and indicates which are used, in conjunction with the appropriate failure criteria, to predict service life values.

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Component or Material	Type Test	No. of Specimen Placed in Storage	1960 J	F	M	A	M	J	J	A	S	O	N	D	1961 J	F	M	A	M	J	J	A	S	O	N
Igniter	Temp cond, functional Transportation cond, x-ray Flt cond, x-ray, funct, static fire Flight cond, x-ray, dissect X-ray	37																							
Failure criteria study	Static test and dissection	17																							
Igniter S & A	Temp cond, functional Transportation cond, electrical Flt cond, functional, static fire	28																							
Pellets	Physical & chemical on "new" pellets Physical & chemical on "old" pellets																								
TT switch -5	Transportation vibration, electrical	11																							
-5	Flight cond, functional, destruct																								
-9	Transportation vibration, electrical	11																							
-9	Flight cond, functional, destruct																								
-11	Transportation vibration, electrical	24																							
-11	Flight cond, functional, destruct																								
Frangible sectors Wing I	Transportation vibration electrical Flight vibration	120												11											
Wing II	Transportation vibration electrical Flight vibration	152																							
Nozzles Wing I	Pressure leak, cold torque, NDT Mechanical cycle X-ray, disassemble Hand cycle	16																							
Wing II	Pressure leak, cold torque, NDT X-ray, disassemble Hand cycle	7																							
Spiralloy																									
Wafer lap shear, Type 1 (cyl)	Physical	260																							
Layer lap shear, Type 1 (cyl)	Physical	400																							
Wafer lap shear, Type 1 mat (cyl)	Physical																								
Layer lap shear, Type 2 (cyl)	Physical																								
Wafer bottles	Hydroburst	21																							
Oval..d bottles	Hydroburst	40																							
Short beam shear (lab)	Physical	704																							
Uncoated NOL rings	Physical	440																							
Coated NOL rings	Physical	72																							
FSU cases, Wing I	Hydroburst	6																							
FSU LS & SBS, Wing I	Physical	272																							
FSU cases, Wing II	Hydroburst	2																							
FSU LS & SBS, Wing II	Physical	368																							
Failure criteria study																									
Interlaminar shear ring I	Physical	504																36	36	36			36		
Interlaminar shear ring II	Physical	440																							
Propellant	Physical & chemical	94																							
	Physical & chemical	1816												16	32	24	56	56	24	32	32		56	24	16
	Subscale static	107			1	2	2	1	3	2	1	5	4	1	4	3	1	6	4	1	4	3	1		
Failure criteria study																									
FSU Grain Dissection																									

TABLE 1-1A

MASTER SURVEILLANCE TEST SCHEDULE

1961

M	J	J	A	S	O	N	D
							34 3
36	36	36		36			36
56 3	24 1	32 6	32 4 1	56 4	24 3	16 1	24 4

1962

J	F	M	A	M	J	J	A	S	O	N	D
										21	
										21	
								2			8
		3		10			10		11	112	69 4
		36			36			36			36
16 3	8 1	24 4	16 4	1	24 3	8 3	1	24 6	8 4	8 1	24 4

1963

J	F	M	A	M	J	J	A	S	O	N	D
		8			8			8			8
			5			6					
		2	1	8 2			9 8	6	11 1	136 8	73
16						4 2 8					
				10				32 20		5	32 20
		36	50		36	50		36	50		36
8 3	1	24 4	8 3	1	24 2			16 4			16 2

1964

J	F	M	A	M	J	J	A	S	O	N	D
		1		4 3	2	3		2			
		1		4 3	2	3		2			
		8			8			8			
			2 2			2 2					
	1	2		7 1 8	4		8	1	9 2	120 8	69
8 4 8						4 2 8					7
		32 20		5	32 20			32 20		5	32 20 1
50			50			50			50		
		2									

1965

J	F	M	A	M	J	J	A	S	O	N	D
1 2		6								3 2	2
1 2		6								3 2	2
1		8						8			
			2 2 24			1 2					
	1	1		6 1 8	3		7		9	104 8	60 6
8 4 8					7	4 2 8				2 2 1	6
		32 20		5	32 20	8		32 20		5	32 20
50				36	40						
					2 171						2 149
		1			1	1	1			1	

Component or Material	Type Test	No. of Specimen Placed in Storage	1966 J	F	M	A	M	J	J	A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	J
Igniter	Temp cond, functional	37																									
	Transportation cond, x-ray		3										2	2	3											2	
	Flt cond, x-ray, funct, static fire		1			3									1				2				1		1		
	Flight cond, x-ray, dissect		1						1								1						1				
	X-ray																										
Failure criteria study	Static tests and dissection	17									3		1		3			3						3			
Igniter S & A	Temp cond, functional	28																									
	Transportation cond, electrical		3										2	2	3											2	
	Flt cond, functional, static fire		1			3									1				2				1		1		
Pellets	Physical & chemical on "new" pellets				8						8						8						8				
	Physical & chemical on "old" pellets		1						1								1						1				
TT switch -5	Transportation vibration, electrical	11																									
-5	Flight cond, functional, destruct					1																					
-9	Transportation vibration, electrical	11																									
-9	Flight cond, functional, destruct								2																		
-11	Transportation vibration, electrical	24				9												12									
-11	Flight cond, functional, destruct					2												2									
Frangible sectors Wing I	Transportation vibration, electrical	120					3					9		58										8		47	
	Flight vibration			6	1		4			1				2				1	3	5						6	
Wing II	Transportation vibration, electrical	152											88												72		
	Flight vibration						8						8						8						8		
Nozzles Wing I	Pressure leak, cold torque, NDT	16	8						4						8						4						4
	Mechanical cycle		4						2						4						2						4
	X-ray, disassemble																										
	Hand cycle		6						6						6						6						6
Wing II	Pressure leak, cold torque, NDT	7																									
	X-ray, disassemble																										
	Hand cycle							6						6						6						6	
Spiralloy																											
Wafer lap shear, Type 1 (cyl)	Physical	260																		28							
Layer lap shear, Type 1 (cyl)	Physical	400												28						28						28	
Wafer lap shear, Type 1 mat (cyl)	Physical																										
Layer lap shear, Type 2 (cyl)	Physical																										
Wafer bottles	Hydroburst	21														3											
Ovaloid bottles	Hydroburst	40					5																				
Short beam shear (lab)	Physical	704			32			32			32						32						32				
Uncoated NOL rings	Physical	440			20			20			20						20						20				
Coated NOL rings	Physical	72	8						8						8						8						
FSU cases, Wing I	Hydroburst	6	1	1					1						1												
FSU LS & SBS, Wing I	Physical	272	48	32											32						16						3
FSU cases, Wing II	Hydroburst	2																						1			
FSU LS & SBS, Wing II	Physical	368	8	8					8	8					8	8					8	8		16			
Failure criteria study																											
Interlaminar shear ring I	Physical	504																									
Interlaminar shear ring II	Physical	440																									
Propellant	Physical & chemical	94						2						14	12					14						18	1
	Physical & chemical	1816	28					208	84					96						12						84	84
	Subscale static	107																									
Failure criteria study																											
FSU Grain Dissection																										1	

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1967							1968												1969												1970												1971											
J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
						2	3											1	2												1																							
			1		1						1	1					1	1							2		1			2					2		1																	
			1						1						1						1						1																											
				3						3 (1 unit held for backup)																																												
						2	3											1	2												1																							
			1		1						1	1					1	1							2		1			2					2		1																	
			8																																																			
			1						1						1						1						1																											
										7												9												5												6								
										2												3												2												3								
				8		47										5		37										2		20										1														
5						6						6				3		4						11				3		6						12				1		8				1								
					72												56												40												24												12	
					8						8						8						8						8						8						8						6						6	
	4						8						4						8						4						8						4						8						4					
	2						4						2						4						2						4						2						4						2					
							1												1												1												1											
	6						6						5						5												4						3						3						2					
																														1												1												1
6						6						6						6						6						6						5						5						4						4
28												28												28												28												28						
28						28						28						28						28						28						28						28						28						
								3												3												3												3										
			32						32						32												32												32												32			
			20						20						20												20												20												20			
	8						8						8												8												8																	
							1																																															
	16						32	16											32												16												16	16										
				1																								1																										
	8	8		16			8	8					8			16			8	8								32			8	8								16												16		
14						18	12					2						2						2						2						2						2						2						2
12						84	84						28						84						28						84						28																	
						1																																																

Component or Material	Type Test	No. of Specimen Placed in Storage	1972												1973												
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Igniter	Temp cond, functional	37																									
	Transportation cond, x-ray																										
	Flt cond, x-ray, funct, static fire																										
	Flight cond, x-ray, dissect																										
	X-ray																										
Failure criteria study	Static test and dissection	17																									
Igniter S & A	Temp cond, functional	28																									
	Transportation cond, electrical																										
	Flt cond, functional, static fire																										
Pellets	Physical & chemical on "new" pellets																										
	Physical & chemical on "old" pellets																										
TT switch -5	Transportation vibration, electrical	11																									
-5	Flight cond, functional, destruct																										
-9	Transportation vibration, electrical	11																									
-9	Flight cond, functional, destruct																										
-11	Transportation vibration, electrical	24				3												3									
-11	Flight cond, functional, destruct					2												3									
Frangible sectors Wing I	Transportation vibration, electrical	120																									
	Flight vibration																										
Wing II	Transportation vibration, electrical	152																									
	Flight vibration						6						6														
Nozzles Wing I	Pressure leak, cold torque, NDT	16	8						4						8												
	Mechanical cycle		4						2						4												
	X-ray, disassemble		1												9												
	Hand cycle		2						1						1												
Wing II	Pressure leak, cold torque, NDT	7																									
	X-ray, disassemble													1												1	
	Hand cycle							3						3						2						2	
Spiralloy																											
Wafer lap shear, Type 1 (cyl)	Physical	260						24												24							
Layer lap shear, Type 1 (cyl)	Physical	400						24												24							
Wafer lap shear, Type 1 mat (cyl)	Physical																										
Layer lap shear, Type 2 (cyl)	Physical																										
Wafer bottles	Hydroburst	21		3												3											
Ovaloid bottles	Hydroburst	40																									
Short beam shear (lab)	Physical	704									32												32				
Uncoated NOL rings	Physical	440									20												20				
Coated NOL rings	Physical	72																									
FSU cases, Wing I	Hydroburst	6																									
FSU LS & SBS, Wing I	Physical	272														16											
FSU cases, Wing II	Hydroburst	2																									
FSU LS & SBS, Wing II	Physical	368										32															
Failure criteria study																											
Interlaminar shear ring I	Physical	504																									
Interlaminar shear ring II	Physical	440																									
Propellant	Physical & chemical	94						1						1													
	Physical & chemical	1816																									
	Subscale static	107																									
Failure criteria study																											
FSU Grain Dissection																											

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1973						
J	J	A	S	O	N	D
2						1 2
24 24			32 20			

1974											
J	F	M	A	M	J	J	A	S	O	N	D
			1 2								
					1						1 1
					24 24						

1975											
J	F	M	A	M	J	J	A	S	O	N	D
			3								
					24 24						

1976											
J	F	M	A	M	J	J	A	S	O	N	D
					24 24						

1977											
J	F	M	A	M	J	J	A	S	O	N	D

2

Item	Type Test	No. of Specimen Placed in Storage	1960 J	F	M	A	M	J	J	A	S	O	N	D	1961 J	F	M	A	M	J	J	A	S	O	N	D	1962 J	F
Propellant-to-liner bond FSU I	Physical & chemical	180																										
	Physical & chemical	8																										
FSU II	Physical & chemical	186																										
	Physical & chemical	8																										
Failure criteria study																												
System -1	Physical	36		4	8	8	8			8																		
-2		36		4	8	8	8			8																		
-3		34		4	6	8	8			8																		
-4		60		4	8	8	8			8			4			4			4			4			4			4
-5		56		4	8	8	8			8			4			4			4			4			4			
-6		60		4	8	8	8			8			4			4			4			4			4			4
-7		27						2	2	2	3			2			3			2			3			2		
-9		120												6	8	8	8			8			8			8		
-10	Physical	59						3	4	4	4			4			4			4			4			4		
Case Bond -11	Physical	81												6	6	6	6			6			6			6		
-12		84													6	6	6			6			6			6		
-13		172																										
-15	(BSD Effort)	128																										
-17	(BSD Effort)	120																										
-18	(BSD Effort)	120																										
-19	(BSD Effort)	248																										
-20		135																										
-21	(BSD Effort)	141																										
-22	Physical (BSD Effort)	138																										
Internal Insulator FSU I	Physical	96																										
	Subscale static (Erosion)	23																										
FSU II	Physical	48																										
	Subscale static (Erosion)	8																										
Failure criteria study																												
RPD 150 Phenolic	Physical	99									9			9			9			9			9			9		12
Buna N	Physical	92																										
Buna S	Physical	483																										
External Insulation Avcoat	Physical	354																										
Cork	Physical	2880																										
	Fungus	240																										
Pressure Seal	Physical	3884							48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Elastomer	Physical	380								20			40			40			40			40			40			40
Greases	Physical	46									2	4	4			4			4			4			4			4
Adhesive and Potting Compound J 1170-E18	Physical	176																										
A 12 T		176																										
934		176																										
DCQ-9-0024		88																										
937.2		88																										
RTV77		88																										
RTV88		88																										
923		176																										
C-7		176																										
Thixon CB2		88																										
C-7/SBR 80/20		240																										
C-7/SBR 60/40		240																										
C-7/NBR 80/20		240																										
C-7/NBR 60/40		240																										
923.2/SBR	(BSD Effort)	240																										
923.2/NBR	(BSD Effort)	240																										
B-1 Fix/BPC No. 1	Physical	44																										
CYH/BPC No. 1	Chemical	66																										
B-1 Fix/BPC No. 2	Physical (BSD Effort)	44																										
948.2/953	Physical (BSD Effort)	176																										
948.2/SBR	Physical (BSD Effort)	264																										
948.2/SBR	Peel (BSD Effort)																											
Boot-to-flap	Peel (BSD Effort)																											
FSU Motors Wing I	Static fire	17																							1			
Wing II	Static fire	6																										
Wing IV	Static fire	4																										
Wing VI	Static fire (BSD Effort)	2																										

11

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1961							
M	J	J	A	S	O	N	D
4			4			4	
4			4			4	
4			4			4	
	2			3			2
	8			8			8
	4			4			4
	6			6			6
	6			6			6
	9			9			9
48	48	48	48	48	48	48	48
40			40			40	
4			4			4	
							1

1962											
J	F	M	A	M	J	J	A	S	O	N	D
	4										
	4										
		3			3						
		8			8			8			8
		4			4			4			4
		6			6			6			5
		6			6			6			6
						16			8		
		9			9			9			
	.2			8			8			8	
							39			24	
48	48	48	48	48	48	48	48		48	48	48
	40			40			40				
	4			4			4				
		1			1				1		

1963											
J	F	M	A	M	J	J	A	S	O	N	D
		8			8			4			4
		4			4						
		6			6			3			
		6			6			6			
				16			8			8	
8			8			8			8		
				8			8			8	
				8			8			8	
		9						9			
	8			8			8			8	
									50		
	29			29			34			24	
											240
									16		
48		48	48		48	48			48		
	40										
	4						4				
1			1				1				

1964											
J	F	M	A	M	J	J	A	S	O	N	D
	8			8			8			16	
16			8			16					
	8			8						8	
	8			8						8	
							6			3	
	8						8				
5			22			10			22		
	34			24			34			10	
		240			240			240			240
16			16			16			16		
48											
					16						8
					16						8
					16						8
					8						4
					8						4
							8				
							16				
									4		
					1						1

1965											
J	F	M	A	M	J	J	A	S	O	N	D
						18					18
						1					1
						18					18
						1					1
	8			16						16	
8						8					
										16	
	6			3			3			3	
					6	6					6
							2				
					6						6
						1					
	8										
13			22			13			22		
	29			5			39				
		120			120			120			
16			16			16			16		
		30	30	30	30	30	30	30	30	30	30
					16						8
					16						8
					16						8
					8						4
					8						4
				8						4	
				8						4	
8	4					4	8				
	8						16				
										8	
				4						4	
			6						6		
										4	
										1	
				1							

2

	Type Test	No. of Specimen Placed in Storage	1966												1967														
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Propellant-to-liner bond FSU I	Physical & chemical	180						6						18						6						18			
	Physical & chemical	9												1												1			
FSU II	Physical & chemical	186						6						18						6						18			
	Physical & chemical	8												1												1			
Failure criteria study																													
System -1	Physical	36																											
-2		36																											
-3		34																											
-4		60																											
-5		56																											
-6		60																											
-7		27																											
-9		120																											
-10	Physical	59																											
Case Bond -11	Physical	81																											
-12		84																											
-13		172					8												8						8				
-15	(BSD Effort)	128	8					Hold 8 specimens for backup																					
-17	(BSD Effort)	120						Hold 72 specimens for backup																					
-18	(BSD Effort)	120						Hold 72 specimens for backup																					
-19	(BSD Effort)	248		16			16			16						16						16						16	
-20		135		6			3			6						6						6						6	
-21	(BSD Effort)	141			o				Hold 135 specimens for backup																				
-22	Physical (BSD Effort)	138				3			6			3			6			3			6			3			6		
Internal Insulator FSU I	Physical	96	6					6	6					6	6					6	6						6		
	Subscale static (Erosion)	23		2						2				1		2				1		1				1		1	
FSU II	Physical	48												6												6			
	Subscale static (Erosion)	8							1												1								
Failure criteria study																													
RPD 150 Phenolic	Physical	99																											
Buna N	Physical	92																											
Buna S	Physical	483				16						22						16						22					
External Insulation Avcoat	Physical	354																											
Cork	Physical	2880			120						120						120						120						120
	Fungus	240				16						16												16					
Pressure Seal	Physical	3884	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Elastomer	Physical	380																											
Greases	Physical	46																											
Adhesive and Potting Compound J 1170-E18	Physical	176						16						8						16						8			
A 12 T		176						16						8						16						8			
934		176						16						8						16						8			
DCQ-9-0024		88						8						4						8						4			
937.2		88						8						4						8						4			
RTV77		88					8						4						8						4				
RTV88		88					8						4						8						4				
923		176	8	4					4	8					8	4					4	8					8	4	
C-7		176		8						16						8						16						8	
Thixon CB2		88					4						8						4						8				
C-7/SBR 80/20		240					12						24						12						24				
C-7/SBR 60/40		240					12						24						12						24				
C-7/NBR 80/20		240					12						24						12						24				
C-7/NBR 60/40		240					12						24						12						24				
923.2/SBR	(BSD Effort)	240					12						24						12						24				
923.2/NBR	(BSD Effort)	240					12						24						12						24				
B-1 Fix/BPC No. 1	Physical	44					4						4						4						4				
CYH/BPC No. 1	Chemical	66				6						6						6											
B-1 Fix/BPC No. 2	Physical (BSD Effort)	44					4						4						4						4				
948.2/953	Physical (BSD Effort)	176			16						8						16						8						16
948.2/SBR	Physical (BSD Effort)	264			24						12						24						12						24
948.2/SBR	Peel (BSD Effort)	264					24						12						24						12				
Boot-to-flap	Peel (BSD Effort)	132								12						6						12						6	
FSU Motors Wing I	Static fire	17						1						1											1				
Wing II	Static fire	6			1											1												1	
Wing IV	Static fire	4											1																
Wing VI	Static fire (BSD Effort)	2																											

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1967

M	J	J	A	S	O	N	D
	6						18
							1
	6						18
							1
8						8	
			16				
			6				
		6			3		
	6	6					
	1		1				1
							6
		1					
					22		
				120			
					16		
30	30	30	30	30	30	30	30
	16						8
	16						8
	16						8
	8						4
	8						4
8						4	
8						4	
		4	8				
			16				
4						8	
12						24	
12						24	
12						24	
12						24	
12						24	
12						24	
4						4	
					[illegible]		
4						4	
				8			
				12			
24						12	
			12				
						1	

1968

J	F	M	A	M	J	J	A	S	O	N	D
					6						18
											1
					6						18
											1
				8						8	
	16						16				
	6						6				
6			6						6		
6						6					
	1				1		1				
											6
						1					
			16						22		
		120						120			
									16		
30	30	30	30	30	30	30	30	30	30	30	30
					16						8
					16						8
					16						8
					8						4
					8						4
				8						4	
				8						4	
8	4					4	8				
	8						16				
				4						8	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				4						4	
			6						6		
				4						4	
		16						8			
		24						12			
				24						12	
	6						12				
				1						1	
	1										
										1	
					1						

1969

J	F	M	A	M	J	J	A	S	O	N	D
					6						18
											1
					6						18
											1
				4						8	
	16						16				
	6						6				
			6						6		
6											
1	1					1					
											6
						1					
			16						22		
								120			
30	30	30	30	30	30	30	30	30	30	30	30
					16						
					16						
					16						
					8						
					8						
				8						4	
				8						4	
8	4					4	8				
	8						16				
				4						8	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				4						4	
			6						6		
				4						4	
		16						8			
		24						12			
				24						12	
	6						12				
						1					
	1										
										1	

1970

J	F	M	A	M	J	J	A	S	O	N	D
					6						18
											1
					6						18
											1
										4	
	16						8				
	6						6				
			6						6		
1						1					
											6
						1					
			16						22		
								120			
30	30	30	30	30	30	6	6	6	6	6	6
					8						
					8						
					8						
					4						
					4						
				8							
				8							
8							4				
							8				
				4						8	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				12						24	
				4							
			2								
				4						4	
		16						8			
		24						12			
				24						12	
	6						12				
			1								
1											
										1	
					1						

1971

J	F	M	A	M	J	J	A	S	O	N	D
					6						18
											1
					6						18
											1
				4							
	8						8				
	6						6				
			6						6		
					6						6
							1				
											6
						1					
			16						22		
								120			
6	6	6	6	6	6	6	6	6	6	6	6
					8						
					8						
					8						
					4						
					4						
				4							
				4							
4							4				
							8				
										4	
										12	
										12	
										12	
										12	
										12	
										12	
		16									
		24									
				24							
	6										

		Type Test	No. of Specimen Placed in Storage	1972												1973															
				J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	/	S	O	N	D	J	F	M	A
Propellant-to-liner bond	FSU I	Physical & chemical	180																												
		Physical & chemical	8																												
	FSU II	Physical & chemical	186						6																						
		Physical & chemical	8																												
Failure criteria study																															
	System -1	Physical	36																												
	-2		36																												
	-3		34																												
	-4		60																												
	-5		56																												
	-6		60																												
	-7		27																												
	-9		120																												
	-10	Physical	59																												
Case Bond	-11	Physical	81																												
	-12		84																												
	-13		172																												
	-15	(BSD Effort)	128																												
	-17	(BSD Effort)	120	→																											
	-18	(BSD Effort)	120																												
	-19	(BSD Effort)	248		8						8						8						8						8		
	-20		135		6						6						6						6						6		
	-21	(BSD Effort)	141																												
	-22	Physical (BSD Effort)	138				6						6						6						6						6
Internal Insulator	FSU I	Physical	96												6																
		Subscale static (Erosion)	23	1													1														
	FSU II	Physical	48																												
		Subscale static (Erosion)	8							1																					
Failure criteria study																															
RPD 150 Phenolic		Physical	99																												
Buna N		Physical	92																												
Buna S		Physical	483				16						22						16						22						
External Insulation	Avcoat	Physical	354																												
	Cork	Physical	2880									120												120							
		Fungus	240																												
Pressure Seal		Physical	3884	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Elastomer	Physical	380																												
	Greases	Physical	46																												
Adhesive and Potting Compound	J 1170-E18	Physical	176						8												8										
	A 12 T		176						8												8										
	934		176						8												8										
	DCQ-9-0024		88						4												4										
	937.2		88						4												4										
	RTV77		88					4												4											
	RTV88		88					4												4											
	923		176	4							4					4							4					4			
	C-7		176								8												8								
	Thixon CB2		88										4													4					
	C-7/SBR 80/20		240										12													12					
	C-7/SBR 60/40		240										12													12					
	C-7/NBR 80/20		240										12													12					
	C-7/NBR 60/40		240										12													12					
	923.2/SBR	(BSD Effort)	240										12													12					
	923.2/NBR	(BSD Effort)	240										12													12					
	B-1 Fix/BPC No. 1	Physical	44										12													12					
	CYH/BPC No. 1	Chemical	66																												
	B-1 Fix/BPC No. 2	Physical (BSD Effort)	44																												
	948.2/353	Physical (BSD Effort)	176			8												8												8	
	948.2/SBR	Physical (BSD Effort)	264			12												12												12	
	948.2/SBR	Peel (BSD Effort)	264						12											12											
	Boot-to-flap	Peel (BSD Effort)	132		6												6												6		
FSU Motors	Wing I	Static fire	17																												
	Wing II	Static fire	6																												
	Wing IV	Static fire	4																												
	Wing VI	Static fire	2																												

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1973								
A	M	J	J	A	S	O	N	D
				8				
				6				
6						6		
16						22		
					120			
6	6	6	6	6	6	6	6	6
		8						
		8						
		8						
		4						
		4						
	4							
	4							
				4				
				8				
							4	
							12	
							12	
							12	
							12	
							12	
							12	
							12	
	12							

1974											
J	F	M	A	M	J	J	A	S	O	N	D
	8						8				
	6						6				
							6		6		
6	6	6	6	6	6	6	6	6	6	6	6
					8						
					8						
					8						
					4						
					4						
				4							
				4							
4							4				
							8				
										4	
										12	
										12	
										12	
										12	
										12	
										12	
										12	
		8									
		12									
				12							
	6										

1975											
J	F	M	A	M	J	J	A	S	O	N	D
							6		6		
6	6										
				4							
				4							
4											
										4	
										12	
										12	
										12	
										12	
										12	
										12	
										12	
		8									
		12									
				12							
	6										

1976											
J	F	M	A	M	J	J	A	S	O	N	D
	1										
		8									
		12									
				12							
	6										

1977											
J	F	M	A	M	J	J	A	S	O	N	D

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TABLE 1-2

LABORATORY EXTENSION PROGRAM

Items	Wing Coverage		Approximate Gain or Loss of Leadtime (mo)*
	Original	Extension	
Igniter	I thru VI	I thru VI	-3
Igniter pellets	I thru VI	I thru VI	+1
TT A/D switch	I and II	I thru VI	-6
Nozzles	I	II thru VI	+6
Propellant	I thru VI	I thru VI	+19
Case bond system	I and II	I thru VI	+2
Spiralloy case	I and II	I thru VI	+11
Frangible sectors	I thru VI	I thru VI	0
Internal insulation			
Buna-N	I	I	0
Buna-S	II thru VI	II thru VI	+2
Asbestos phenolic	I	I	0
Nylon phenolic	None	II thru VI	+2
Pressure seals	I	I thru VI	+6
External insulation	I thru VI	II thru VI	-2
Adhesives and potting materials			
Seam sealing (CS)	None	I thru V	+6
RTV-88	None	I thru VI	-36
RTV-77	None	I thru VI	-36
C-7 (80/20)	None	I thru VI	-36
C-7 (60/40)	I	I thru VI	0
Epon 923	None	II thru VI	-22
Tixon CB2	None	I thru VI	-36
Urethane potting	None	I thru VI	+19
BPC- No. 1	None	II thru V	0
A-12-T	None	I thru VI	-36
Epon 934	None	II thru VI	-22
Epon 923.2	None	II thru VI	-22
Epon 937.2	None	II thru VI	-22
DCQ-9-0024	None	I thru VI	-36
Epon 948.2	None	VI	0
Epon 953	None	VI	0
BPC- No. 2	None	VI	-2

* Leadtime is based on oldest motors of each wing in operational force at time of program extension (Nov 1964)

TABLE 1-3

MASTER GRAIN DISSECTION AND MATERIAL TEST SCHEDULE

Operation	Grain No.*	Date of Test and Age of Material Tested (yr)															
		2-1/2	3	3-1/2	4	4-1/2	5	5-1/2	6	6-1/2	7	7-1/2	8	8-1/2	9	9-1/2	10
Dissect grains into sample sections and place sections into storage**	336	6/65															
	216			5/65													
	131					8/65											
	67							11/65									
	70											12/67					
	1-M-1	7/65															
Remove propellant sample sections from storage, machine into specimens, and test	336	7/65	1/66	7/66													
	216			6/65	12/65	6/66											
	131					8/65	2/66	8/66									
	67							12/65	6/66	12/66	6/67	12/67					
	70											1/68	7/68	1/69	7/69	1/70	7/70
Remove case bond sample sections from storage, machine into specimens, and test	336	7/65	1/66	7/66	1/67	7/67	1/68	7/68	1/69	7/69	1/70	7/70	1/71	7/71	1/72	7/72	1/73
	216			6/65	12/65	6/66	12/66	6/67	12/67	6/68	12/68	6/69	12/69	6/70	12/70	6/71	12/71
Remove phenolic internal insulation sample section from storage, machine into specimens, and test	336	7/65		7/66		7/67		7/68		7/69		7/70		7/71		7/72	
	131					8/65	2/66	8/66	2/67								
	67									12/66	6/67	12/67	6/68				
	70													1/69	7/69	1/70	7/70
	1-M-1	8/65	2/66	8/66	2/67												
Remove rubber internal insulation sample section, machine, and test	336	7/65		/66		7/67		7/68		7/69		7/70		7/71		7/72	
	131					8/65	2/66	8/66	2/67	8/67	2/68	8/68	2/69				
	1-M-1	8/65	2/66	8/66	2/67	8/67								8/71	2/72		2/73
Remove fwd dome from storage for test and inspections	336						1/68										
	216							6/67									
	131								2/67								
	67									12/66							
	70											1/68					
Remove aft dome from storage for test and inspections	336						1/68										
	216							6/67									
	131								2/67								
	67									12/66							
	70											1/68					
	1-M-1						2/68										

*Grain cast dates and configuration:

336 - December 1962, Wing II
216 - December 1961, Wing I (used for propellant and case bond studies only)
131 - January 1961, Wing I
67 - June 1960, Wing I
70 - July 1960, Wing I
1-M-1 - December 1962, Wing I

**See Appendix B for dissection details

TABLE 1-4

BASIC CONFIGURATION FOR DISSECTED GRAINS

Grain No.	Internal Insulation		Case		Case-Bond System		External Insulation Material
	Vendor*	Material (rubber/phenolic)	Vendor*	Material (type/finish/resin)	Adhesive	Propellant	
216	GYR	NBR/Asbestos	RH	E/801/828	923	CYH	Avcoat
336	GYR	SBR/Nylon	RH	E/HTS/2256	923	CYH	Cork
131	USR	NBR/Asbestos	RH	E/801/828	X-81	CYH	None
67	USR	NBR/Asbestos	BS&B	E/801/828	C-7	CYH	None
70	USR	NBR/Asbestos	BS&B	E/801/828	C-7	CYH	None
IMI	GYR	NBR/Asbestos	HPC Plant II	E/HTS/826	923	CYH	Avcoat

*Vendor:
GYR - Goodyear Tire and Rubber Co
USR - U. S. Rubber Co
RH - Hercules' Rocky Hill, New Jersey Plant
BS&B- Black, Sivalls, and Bryson

TABLE 1-5

TEST PARAMETERS

Test Item	Parameter	Data Used For Service Life Predictions
Ignition system		
Igniter	Max pressure(1)	X
	Avg pressure	X
	Ignition delay	X
	Burning time	--
	Impulse	--
	Chemical changes	--
S & A device	Actuation current	--
	Actuation time	--
Ignition pellets	Heat of reaction	--
	Impact sensitivity	--
	Moisture content	--
	Vibration resistance	--
	Energy to ignite	X
	Energy liberated	X
TT system		
A/D switch	Arming time	--
	Arming circuit resistance	--
	Firing circuit resistance	X
Frangible sectors	Actuation time	X
	Fragmentation	--
	Bridgewire resistance(2)	X
Nozzles		
Nozzle assembly	Cold torque	X
	Pressure leak	X

(1)Current failure criteria values = 910 psia (pending results of Igniter Failure Criteria Study)

(2)Current failure criteria values = 0.21 ohms (based on specification limit)

TABLE 1-5 (Cont)

TEST PARAMETERS

Test Item	Parameter	Data Used for Service Life Predictions
Case		
Tensile shear specimens	Interlaminar shear[3]	X
	Short beam shear[4]	X
	Lap shear	X
	Hoop tensile	--
Wafer bottles	Burst pressure	--
FSU cases	Burst pressure	--
Internal insulation		
Rubber	Tensile	--
	Elongation[5]	X
	Density	--
	Hardness	--
	Erosion	X
	NG migration	--
Phenolic	Tensile	--
	Hardness	--
	Elongation	--
	Erosion	X
External insulation		
Avcoat	Tensile	--
	Elongation	--
	Hardness	--
Cork	Tensile	--
	Hardness	--
	Elongation	--
	Density	--

[3]Current failure criteria values = 50 percent degradation of initial value

[4]Current failure criteria values = 30 percent degradation of initial data (based on case design safety factor)

[5]Current failure criteria values = 3.5 percent (based on hydroburst data on allowable case expansion)

TABLE 1-5 (Cont)

TEST PARAMETERS

Test Item	Parameter	Data Used For Service Life Predictions
Propellant grain	Maximum stress	X
	Strain at max stress	X
	Maximum strain	X
	Stress at max strain	X
	Creep	--
	Relaxation modulus	--
	Chemical changes	X
	Accumulative damage	--
Case bond	Tensile	X
	Peel	--
	Chem profile	X
Adhesives and potting compounds	Tensile	--
	Elongation	--
	Hardness	--
	Peel	--
	Shear	--
	Chemical changes	--

There are many tests and observations made in the Laboratory Support Program which do not provide measurable data. This type of information is recorded by photographs or other means and used in making predictions and performing failure analyses.

The procedure for analyzing and interpreting data has been designed to establish a consistent method for making service life predictions. The procedure is outlined in the following paragraph.

c. Service Life Estimating Procedure

1) Introduction

The minimum service life of motors in the Minuteman propulsion system is normally considered to be the demonstrated storage life determined by the oldest successful full-scale motor firing. However, only limited confidence can be placed on a single motor test. Also, because of the small sample size, minor configurational differences, and the relatively short lead time of the storage motors over the operational force, data from

storage motor firings alone is not sufficient for estimating minimum service life. Supporting data is necessary to confirm and extend the minimum service life estimate. Use should be made of the data from additional motor firings, laboratory component aging studies, the literature, and other storage programs. An early prediction of the minimum service life is essential to avoid excessive unreliability costs and to provide maximum response time so that replacement or retrofit action can be initiated on the most cost effective basis. The minimum service life is defined as the age at which critical propulsion system failures begin to occur due to ageout of components.

The basic assumption in estimating the minimum service life from motor component data is that the useful life of the motor will not be less than the time required for the most age-sensitive component to ageout. Consequently, aging trend data for the individual motor components and materials can be used to predict the minimum service life of the propulsion systems and provide a longer range estimate than is possible from motor firing tests alone. This approach requires a great deal of engineering judgment and many assumptions as follows:

(a) Laboratory aging is comparable to motor aging.

(b) Proper components and materials have been selected for testing.

(c) Proper test methods and parameters have been selected.

(d) Predicted mode of failure is realistic.

(e) Aging trend can be expressed by a mathematical model and reliably extrapolated.

(f) Estimated failure limits will result in a critical motor failure.

Because of these many assumptions, a conservative approach must be used in assessing laboratory component data to avoid unrealistic estimates.

The detailed procedure for estimating service life is contained in TRW, Inc, document 6001-RO 000, dated 10 June 1966. A brief outline of the procedure is contained in the following Paragraphs:

2) <u>Demonstrated Service Life</u>

The demonstrated service life of a motor shall be based on the results of static firings of full-scale motors and flight tests of missiles. In addition to the oldest successful firing, which provides factual evidence of satisfactory performance of at least one unit at this age, an estimate of the probability of additional successful firings at

various ages and the associated confidence level of the probability statements shall be provided. This probability statement is termed the demonstrated probability of no ageout (DPNA) and utilizes all successful aged motor firings to estimate the confidence in the demonstrated service life and to provide estimates of ageout probability beyond the demonstrated service life. It should be noted that the method used to make the statement of probability of no ageout is not intended to predict the reliability of the force after failures have occurred due to aging; additional techniques are necessary to establish a study of this nature.

In calculating probability of no ageout, separate estimates shall be provided for Wings exhibiting significant configurational differences. The DPNA and the associated confidence level shall be determined at 1-yr intervals (starting at 3 yr) on an accumulated age basis.

A demonstrated service life shall also be provided for all motor components. In addition, the DPNA value shall be calculated, when sufficient data are available, for all motor components defined by an Air Force Model Specification.

3) Predicted Minimum Service Life

An estimate of the minimum service life of the motor shall be made from laboratory studies of materials and components. The minimum service life estimate of the motor shall be based on the predicted minimum service life of the most age-sensitive component.

Minimum predicted service life of a component shall be based mainly on trend analyses of data obtained from tests on the component when aged under simulated silo conditions. Accelerated aging data or data obtained under non-silo conditions shall only be used to predict service life when insufficient data is available from storage tests conducted under simulated silo conditions. Estimates based solely on accelerated aging data shall be distinguished by the symbol (A) after the estimate. Accelerated aging data will also be of value in predicting probable failure modes. After more than five data points from ambient storage tests have been obtained, representing at least 2-yr storage, the accelerated aging data shall only be used to confirm the validity of extrapolated ambient trend data. The latter validation shall be done by converting the accelerated data to an equivalent time at ambient, by means of a temperature-time superposition method, or by use of an Arrhenius relationship.

4) Plan for Predicting Minimum Service Life

The general plan, including the essential steps for predicting minimum service life, is shown in Figure 1-1. The basic approach is as follows:

(a) Critical parameters are identified by a careful study of components and materials in the motor.

(b) These parameters are used to detect trends due to age by plotting a curve of data versus time.

(c) Plots similar to the one shown in Figure 1-2 are selected, which will provide a trend line to assist in visual interpretation.

(d) Trend lines are rigidly defined by using standard regression techniques which enable uniform treatment and statistical assessment of the significance of data.

(e) A band representing possible error in assessing trends is placed around each trend line. To provide maximum usefulness, the band selected is a 3 sigma band. This approach enables useful estimates to be made in highly extrapolated regions using the limited number of samples usually available.

(f) A failure criterion is used as the limiting acceptable value for the trend observed. Where possible the failure criteria is analytically or experimentally determined using the performance requirements of the motor as criteria.

(g) When no failure criteria are available, the predicted minimum service life will be obtained by analytically testing the value of the parameter at selected ages to determine the minimum acceptable age. The advantage of this approach is that detailed analysis of failure limits need only be made for items which have critical trend curves at this time.

(h) If the failure criterion has confidence bands associated with it, the service life estimate is based on the limiting or worst case value. Safety factors involved in failure criteria bands are based on the degree of uncertainty.

(i) The conclusion reached from trend analysis regarding minimum service of a component is carefully reassessed in the light of all other available data, and further actions are determined.

(j) Actions resulting from these studies include isolation of age-sensitive items; recommendation for confirmatory tests to affirm validity, reduction, or discontinuance of testing; and, in cases of relatively short-lived components, recommendations concerning replacement.

d. Configuration Differences

To provide maximum lead time in both the laboratory and motor programs, the oldest related data is utilized wherever possible. In many cases, configuration differences exist between the test sample and the operational unit. To apply the older data, therefore, it is necessary to analyze the configuration differences and assess the applicability of the data. If the configuration differences are significant, the service life estimates are based mainly on new samples and the old data used only as a guide in predicting probable failure modes and degradation rates. In many cases, where the configuration differences are slight, the older data is used effectively.

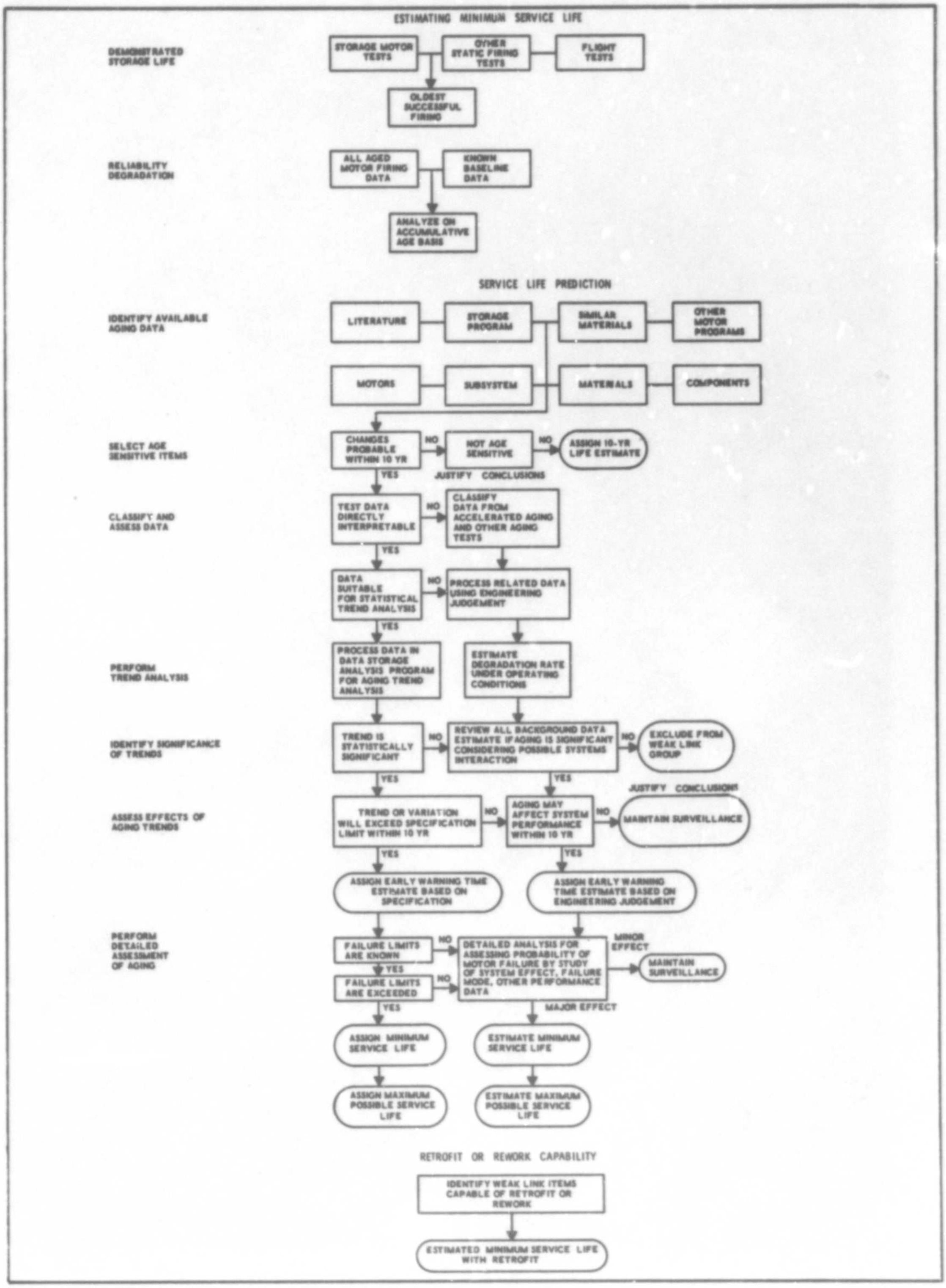

Figure 1-1. Flow Chart for Determining Minimum Service Life

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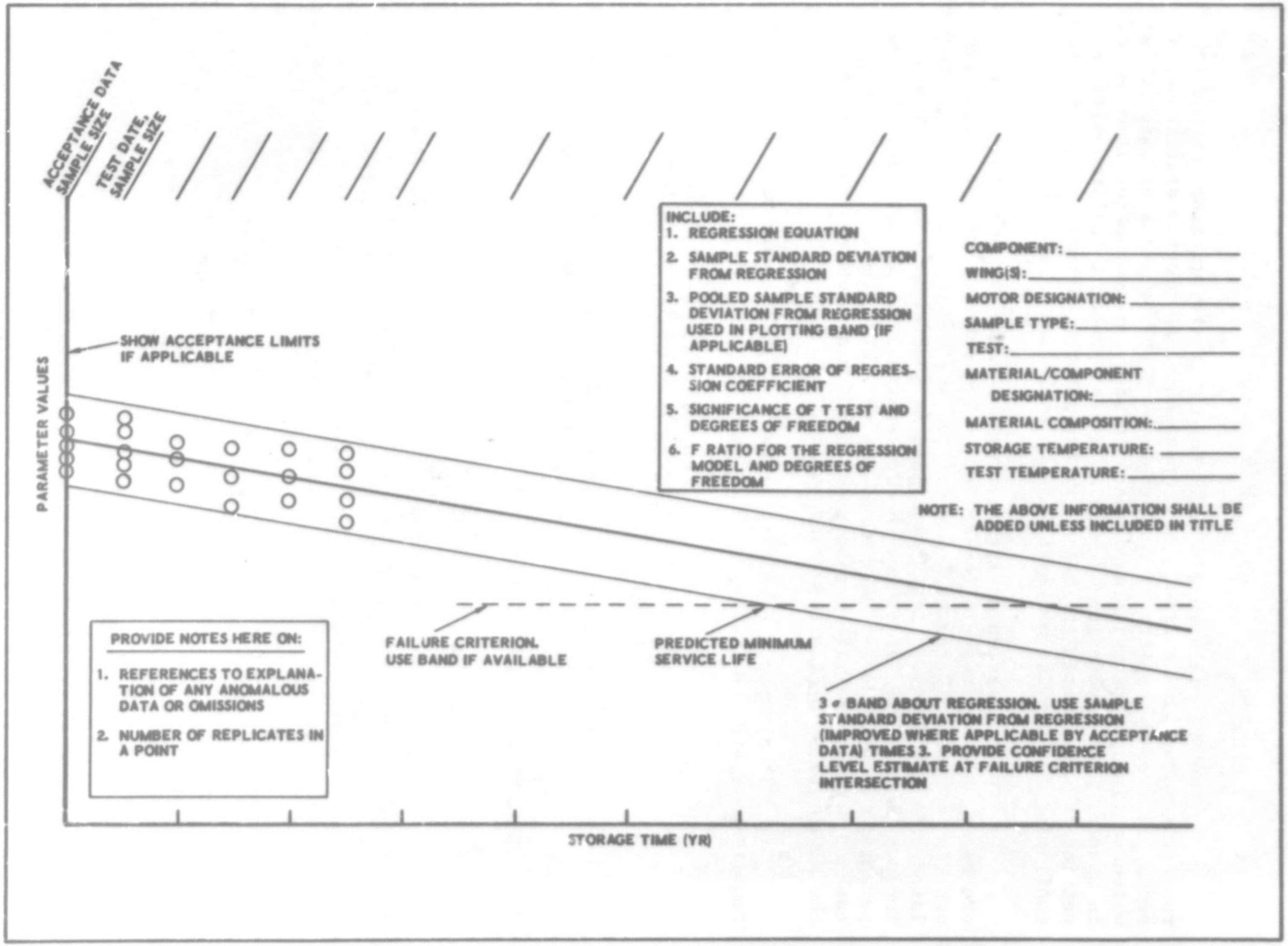

Figure 1-2. Sample Age Trend Curve

7. <u>Reporting</u>

The Surveillance Quarterly Report is the principal method for reporting surveillance data. The report contains program status and data summaries for all aspects of the program. Specific items of information which routinely appear in the report include, for each major item described in Chapter 2, a discussion of problem areas, probable failure modes, a service life estimate, the basis for the service estimate, and plans for confirming the service estimate for the weak-link items.

The regression analysis, from which the service life predictions are based, are included in the report in the form of graphs. These graphs contain a "best fit" regression model for the average data points accumulated from the periodic tests described in Chapter 2. The graphs also include the 3-sigma limits for the regression line, as discussed in paragraph 6, and the 3-sigma values for each time point. Six copies each of the report will be submitted to BSD and OOAMA on the 20th of the month following the reporting period.

Other reports submitted as part of the storage program reporting requirements are the following:

(a) Motor Final Firing Report (described in Chapter 3) which will be submitted on all future Surveillance firings

(b) Surveillance Working Group (SWG) Handout, which is the latest published Surveillance Quarterly Report

C. DEVELOPMENT OF SERVICE LIFE PREDICTION CRITERIA

1. <u>Introduction</u>

Since the accuracy of service life predictions is dependent on the validity of failure criteria, it is imperative that the most accurate failure criteria be established. Failure Criteria Development Studies have been initiated to improve the failure criteria for the items which are considered to have the least reliable criteria and the highest probability of failure.

8. Disposition of Fired Motors and Spent Hardware

The motors, after static testing, are given a complete postfire analysis which includes case and nozzle sectioning. The hardware is photographed to document the condition. The remains are then crated and stored for the duration of the 10-year program.

9. Movement of Classified Type III, Class A Explosive

All storage motors were shipped to the HAFB storage site with igniters and S & A devices installed as Type III, Class A Explosive.

10. Installation of Simulated Flight Hardware

Simulated flight hardware installed on storage motors consists of weights which simulate the loads applied to the motors by the NCU warhead and the flight nozzle exit cone. The hardware is described in Volume II, Chapter 3, Section I. Table 1-9 lists the type of hardware and the dates of installation.

11. Motor Testing

Hercules has successfully demonstrated 4-year storage capabilities of the Wing I stage III Minuteman motors. This capability was demonstrated by firing storage motor 1-5-2 on 30 December 1964. Prior to the 4-year demonstration test, eight motors had been tested, ranging in age from 6 months to 3 years. The testing of the 4-year old motor concluded Hercules responsibility for testing Wing I storage motors. One 26-month-old Wing II motor was also tested successfully.

B. LABORATORY SUPPORT

1. Summary

The Laboratory Support Program was initiated in April 1960. The items placed in storage earliest were those felt to be most susceptible to aging. As the program developed, more items which were susceptible to aging were added. New items were also added as design improvements were made. The status of the continuing portion of the Laboratory Support Program is presented in the Quarterly Report. Duration of programs are shown in the individual test plans.

2. Completed or Discontinued Test Programs

Some of the test programs presented in the preceding program plan, MTO-258-3A, have been discontinued, or the scheduled testing has been completed. These programs were:

(a) Spiralloy interlaminar shear tests

(b) Propellant physical, stability, and ballistics properties tests (constant rate tensile, Taliani, autoignition, and subscale firings)

TABLE 1-9

WINGS I THROUGH VI STORAGE MOTOR HARDWARE INSTALLED

Motor Test No.	Applicable Wing	Nozzle Expansion Ratio	Type of Hardware Installed: Simulated NCU	Type of Hardware Installed: Flight Exit Cones	Type of Hardware Installed: Simulated Warhead Weights	Pyrogen Igniter: Installation Date	Pyrogen Igniter: Manufacture Date	Motor Cast Date
1-5-1	I	6:1				*	--	Nov 60
1-5-2	I	8:1	X	X	X	Dec 64	Feb 63	Nov 60
1-5-3	I	6:1				Dec 62	Nov 62	Dec 60
1-5-4	I	6:1				*	--	Dec 60
1-5-5	I	6:1				Aug 62	Sep 62	May 61
1-5-6	I	8:1		X	X	May 63	Jan 63	Apr 61
1-5-7	I	8:1	X	X	X	Jun 64	Feb 63	May 61
1-5-8	I	8:1	X	X	X	Sep 63	Feb 63	Jun 61
1-5-9	I	8:1	X	X	X	Jun 64	Feb 63	Jun 61
1-5-10	I	18:1				Mar 63	Jan 63	Sep 60
1-5-11	I	6:1	X		X	Sep 62	Sep 62	Apr 62
1-5-12	I	6:1	X		X	Apr 64	Feb 63	Sep 61
1-5-14	I	6:1	X			Jun 64	Mar 63	Feb 62
1-5-15	I	6:1	X		X	Sep 62	Jun 62	Mar 62
1-5-20	I	18:1				*	--	Jan 61
1-5-21	I	18:1	X			Feb 65	May 63	Dec 62
1-5-22	I	18:1	X		X	Jun 62	Jun 62	Jan 62
2-5-1	II	18:1			X	Apr 63	Mar 63	Mar 63
2-5-2	II	18:1	X		X	Apr 63	Feb 63	Mar 63
2-5-3	II	18:1	X		X	Apr 63	Feb 63	Feb 63
2-5-4	II	18:1	X		X	Mar 63	Dec 62	Feb 63
2-5-5	II	18:1	X		X	Mar 63	Dec 62	Feb 63
2-5-6	II	18:1	X		X	Feb 63	Nov 62	Jan 63
4-5-1	IV	18:1	X		X	Dec 63	Dec 62	Nov 63
4-5-2	IV	18:1	X		X	Dec 63	Oct 63	Nov 63
4-5-3	IV	18:1	X		X	Dec 63	Oct 63	Nov 63
4-5-4	IV	18:1	X		X	Dec 63	Jul 63	Nov 63
6-5-1	VI	18:1	X		X	Aug 65	Sep 65	Jun 65
6-5-2	VI	18:1	X		X	Aug 65	Sep 65	Jun 65

*Motors were fired with pellet igniters

SECTION I

IGNITER AND IGNITER SAFE AND ARM SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The D-6 pyrogen igniter, studied under this program, is the configuration used in Wings I through VI stage III motors. The propellant composition, HPC 133-08-6-11, is DDP (80 percent NG). The igniter testing is conducted in two parts. Part one consists of storing and conditioning igniters with igniter Safe and Arm (S & A) devices attached. Part two of the igniter testing consists of dissecting aged igniters and conducting microscopic and chemical inspections.

The igniters scheduled for dissection were approximately 2 years old at the time of storage; therefore, testing will begin with the 2-year test period. The dissected igniters will provide information required for igniter failure analysis studies and supply the pellets required for extending the pellet service life prediction study (Section II) from 3 to 10 years.

The S & A devices under study are the KR-80000-03 and -06 configurations. More detailed service life data on these later configurations can be obtained from the Thiokol Chemical Corporation. The S & A devices are included in this program in order to store the igniters in operational configuration and are not intended for service life prediction. The data obtained is additional information.

B. DETAILED TEST PLAN

1. Acquisition of Samples

The 28 igniters, 10 part No. 01A00560-003 and 18 part No. 01A00560-001, obtained for the performance testing were procured from Hercules' Kenvil Works.

The two igniter configurations are the same, except the No. 01A00560-001 (R & D) has two pressure transducer taps whereas the No. 01A00560-003 (operational) has only one tap. The one pressure tap is used on operational units for installation of the operational pressure transducer.

Of 28 S & A devices procured for this testing program, 10 are part No. KR-80000-06, manufactured by Pelmac Division of Quantic Industries and 18 are part No. KR-80000-03, manufactured by Bulova Research Development Laboratory.

The 16 igniters, part No. 01A00560-1, obtained during December 1964 for dissection, were manufactured by Kenvil Works between December 1962 and March 1963. The temperature of the building in which the igniters were stored is maintained at $70^{\circ} \pm 10^{\circ}$ F.

2. <u>Preparation for Storage</u>

Each igniter is given a complete radiographic and visual inspection prior to storage. The 28 igniters and S & A devices required for the performance testing are assembled together. In order to simulate operational conditions, the igniters are mounted in a storage container, drawing No. 01H02175, which holds the unit in a vertical, base-down attitude.

3. <u>Storage</u>

a. <u>Storage Condition</u>

Igniter assemblies will be stored at 70° ± 10° F and visually inspected bimonthly to detect any external damage, such as corrosion and oxidation. Any significant discrepancy will be photographed, documented, and reported. Withdrawal from storage for conditioning and testing is scheduled in Table 2-1.

4. <u>Conditioning, Inspection, and Test</u>

a. <u>Transportation Vibration Conditioning</u>

Transportation vibration will simulate expected motor transportation. The igniter and S & A assembly will be mounted on an igniter vibration test fixture, drawing No. 01E92713, designed to simulate operational conditions. The vibration requirements are as follows:

(1) Amplitude: 3.5 G rms between 5 to 50 cps; vibration limited to 0.4 in. peak-to-peak

(2) Range: 5 to 50 cps

(3) Duration: Two double sweeps (5 to 50 cps and return to 5 cps for each double sweep) at 1/2 octave per minute

(4) Order of vibration:

(a) Z - axis (Longitudinal)

(b) X - axis (Transverse vertical)

(c) Y - axis (Transverse adjacent)

b. <u>Temperature and Humidity Cycling</u>

Temperature and humidity cycling represents igniter and S & A shipment prior to assembly in the motor. This cycling was conducted

TABLE 2-1

IGNITER AND IGNITER SAFE AND ARM DEVICE TEST SCHEDULE

S & A Serial No.	S & A Dash No.	Igniter Serial No.	Zero Time Date*	Test Sequence (mo from zero time)**													
				***	18	24	36	42	48	54	60	66	72	78	84	90	
000-1-132	-06	0557	Nov 62		c												
000-1-135	-06	0549	Nov 62				c										
000-1-136	-06	0362	Sep 62						c								
000-1-134	-06	0548	Nov 62							c							
000-1-131	-06	0556	Nov 62										c				
000-1-097	-06	0360	Sep 62												c		
000-1-129	-06	0551	Nov 62													c	
000-1-140	-06	0554	Nov 62	b	c												
000-1-130	-06	0364	Sep 62	b		c											
OP10000	-03	0710	Jan 63	b			c										
OP10028	-03	0711	Jan 63	b				c									
OP10024	-03	0708	Jan 63	b					c								
000-1-139	-06	0365	Sep 62	b							c						
000-1-133	-06	0560	Nov 62	b								c					
OP10023	-03	0714	Jan 63	b										c			
OP10019	-03	0702	Dec 62	b											c		
000-1-137	-06	0550	Nov 62	b												c	
000-1-138	-06	0553	Nov 62	b	ac												
000-1-146	-06	0359	Sep 62	b	a	c											
000-1-356	-06	0558	Nov 62	b	a		c										
000-1-145	-06	0552	Nov 62	b	a		a	c									
000-1-096	-06	0555	Nov 62	b	a		a		a	c							
000-1-242	-06	0559	Nov 62	b	a		a		a		c						
OP10015	-03	0713	Jan 63	b	a		a		a		a	c					
OP10008	-03	0703	Dec 62	b	a		a		a		a		c				
OP10026	-03	0705	Jan 63	b	a		a		a		a		a	c			
OP10017	-03	0701	Dec 62	b	a		a		a		a		a		c		
OP10027	-03	0709	Jan 63	b	a		a		a		a		a		a	c	
--	--	0704	Jan 63			d											
--	--	0706	Jan 63			e	d										
--	--	0712	Jan 63			e		d									
--	--	0908	Mar 63			e			d								
--	--	0910	Mar 63			e				d							
--	--	0911	Mar 63			e					d						
--	--	0912	Mar 63			e						d					
--	--	0914	Mar 63			e							d		d		
--	--	0915	Mar 63			e								d			

* = Receiving date

** = Test Sequence:

a = Transportation vibration and inspection

b = Temperature and humidity cycle, mechanical and electrical inspections

c = Flight vibration, X-ray, mechanical and electrical inspections, and firing

d = Flight vibration, X-ray, dissection, and analyzing of parts

e = X-ray

*** = Initial time test

at HPC/B in accordance with the following procedure:

(1) Expose units to room temperature (70° ± 10° F) for 4 hr.

(2) Place units in conditioning oven at 100° F and 70 percent rh for 4 hr.

(3) Set oven at 140° F and maintain 70 percent rh for 16 hr.

(4) Set oven at 100° F for 4 hr at 70 percent rh.

(5) Set oven at 60° F and 10 percent rh for 4 hr.

(6) Set oven at 20° F maintaining 10 percent rh for 16 hr.

(7) Remove units from oven and condition at room temperature for 4 hr.

c. Mechanical and Electrical Cycling

Mechanical and electrical cycling represents the inspections made on the system during the recycle of a missile. The nondestruct inspection and testing, performed at each withdrawal period, will constitute the mechanical and electrical cycling.

d. Operational Vibration and Acceleration Conditioning

Operational vibration and acceleration conditioning will simulate the vibration and acceleration received during flight. The igniter, with S & A device attached, will be subjected to operational vibration and simulated flight accelerations as specified in paragraphs 3.6.2, 3.6.3, and 4.4.4 of Specification HPC-133-08-4-1. The S & A devices will be armed prior to, and during, vibration and acceleration. The electrical circuits will be monitored during vibration and acceleration for contact chatter, variation of resistance, and rotor bounce. The monitoring current will be 500 ma. The vibration fixture to be used is Wyle drawing No. 13-E-478.

e. Inspection Testing Sequence

1) Safe and Arm

The S & A assemblies will be given arm and disarm inspection tests in accordance with specification HPC-133-02-2-2B, paragraph 4.4.2, Specification for Igniter Safe and Arm Device.

2) Igniter

A visual inspection will be made after each conditioning sequence to determine the formation of corrosion, surface cracks, bond

separations, and other external damage. Any significant discrepancy will be photographed and reported.

3) Radiographic Inspection

Radiographic inspections of the igniter will be conducted in accordance with specification HPC-133-02-5-2, General Requirements for Radiographic Inspection. Results of the inspection will be analyzed to determine the presence of voids, separations, cracks, or inclusions not previously observed, and the growth of flaws which existed at the time of acceptance testing. If flaws are observed which are in excess of those defined in specification HPC-133-02-5-2, but the performance during test firing is still within specified limits, the unit will not be classified as a failure. Details and discussion of X-ray inspection will be included in the Surveillance Quarterly Report.

5. Performance Tests

In order to conduct the performance test, the igniter and the igniter S & A device will be separated to gain maximum data. Tests will be conducted for a period of 10 yr, as indicated by the schedule contained in Table 2-1.

a. Safety and Arming Device

After the scheduled conditioning and inspection sequence, the S & A device will be cycled in accordance with specification HPC-133-02-2-2B. The igniter S & A device (arm-to-disarm) will be cycled a minimum of 1000 cycles with an off time of 5 sec between each cycle. After each fifty cycles, function of the unit will be checked in accordance with paragraph 4.4.2.1 of specification HPC-133-02-2-2B. Upon completion of the cycling, the squibs will be fired for functional test.

b. Igniter

The igniter will be fired after undergoing scheduled conditioning and inspection sequences. Testing of the igniter will consist of firing the unit in an altitude chamber (HPC/K drawing No. KD-7624) according to Static Firing Test Plan, Stage III Surveillance.

The operational S & A device is removed from the storage igniters and replaced with a S & A device (HPC/K drawing No. KD 7473) which is designed to permit monitoring of the igniter bottle pressure during static testing of the igniter. This device was used during the Qualification Program of the D-6 igniter, at the Hercules Kenvil Plant which involved testing of over 200 units. The parameters measured or calculated from an igniter static test are as follows:

(1) Average chamber pressure

(2) Burning time

(3) Igniter delay time

(4) Maximum chamber pressure

(5) Mass flow rate

c. Dissection

The igniters scheduled for dissection will be removed from storage at intervals shown in Table 2-1. The dissection will consist of three cuts. The first cut will be made immediately aft of the nozzle to make the igniter nonpropulsive. The second cut will be made 5.75 in. aft of the forward end to allow removal of the igniter pellets and inspection of the pellet retaining screen. The third cut will be made along the longitudinal axis of the forward section allowing inspection of the grain and grain-case interfaces. Testing of the igniter pellets is described in Section II. Dissection will be accomplished in accordance with General Operating Procedure GOP 2A80-75.

The various interfaces will be photographed and retained for comparitive purposes. Portions of the cut-up igniter will be tested for hardness and a chemical analysis will be performed to determine whether the propellant atmosphere changes the properties of coatings, case, CA beaker, interliner, etc. Microscopic examination will be made for changes and degradation. The cork stopper and plastic diaphragms will also be tested for hardness to detect changes in physical properties. Infrared analysis of the cellulose acetate inhibitor will be made to determine the amount of NG migration.

An ignition study will be made in the Kopito furnace, or equivalent. Using a calorimeter to measure the heat input, the changes in ignition properties of aged propellant will be determined. The parameters measured in the ignition study are the energy to ignite the propellant and the energy liberated by the propellant when burning.

Chemical tests as described in Section VII will be performed on the igniter propellant and CA beaker to obtain a chemical profile, which will furnish documentation of any chemical change through the propellant and CA beaker. The dissected igniters will be examined closely for evidence of exudation or NG migration.

A complete examination will be made of metallic parts for corrosion and pitting. This examination will be most critical on the screen and tube which comes in contact with the pellets. The polypropylene basket will be examined to determine any changes which may occur from contact with igniter pellets.

C. DATA EVALUATION

1. Igniter Performance Tests

The data obtained from the igniter performance tests will be used in conjunction with specification limits to predict the service life of

the D-6 pyrogen igniter. A regression analysis of each parameter will be made, using the individual data points. Extrapolation of the regression curve will establish the service life value.

2. Igniter Attribute Tests

The observed condition of the dissected igniters will be recorded by photograph and by written descriptions. The radiographic examination of the igniters to be dissected will be correlated with the evidence obtained after dissection. Data obtained from measurable parameters will be plotted and analyzed for trends. The use of the above data will be limited to failure analysis investigation.

3. Safe and Arm Device Tests

The data obtained from the S & A device tests will be periodically compared with the data obtained from Thiokol to detect possible differences. The data will also be used for failure analysis investigations.

D. FAILURE CRITERIA DEVELOPMENT

Findings of the failure criteria study will be incorporated when the results have been analyzed and determined acceptable for failure criteria limits.

The failure criteria development study detailed in Section XVII will provide failure criteria limits representing motor requirements on ignition delay under operational conditions.

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SECTION II

IGNITER PELLET SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The pyrogen igniters now being used on Wings I through VI motors contain both boron and lead chromate (2070A) pellets and boron and potassium nitrate (NMP-502) pellets.

The pellets will be stored under varying environmental conditions for a period up to 120 mo. Of each pellet type, 2600 gm will be stored. Pellets will be withdrawn and tested for heat of reaction, impact sensitivity, moisture content, and vibration resistance. Pellets required for the first 5-yr testing were procured from the pellet vendor. The additional pellets required to extend the testing to 10 yr were obtained from aged pyrogen igniters. The pellets will be tested when the igniters are dissected at the scheduled intervals from 2 to 10 yr. Tests decribed in this study, except for the micro analysis, are the same as conducted during the qualification of the pellets during the development stage.

B. DETAILED TEST PLAN

1. Acquisition of Samples

The NMP-502 ($BKNO_3$) pellets for this study were manufactured by U.S. Flare Division of Atlantic Research Corporation. The 2070A pellets were manufactured by Bermite Powder Company. Pellets required for the first 5-yr testing were procured for the study directly from the vendor in the quantities indicated in the following tabulation:

Quantity (gm)	Pellet Type
2600	Boron and Lead Chromate, 2070A
2600	Boron and Potassium Nitrate, NMP-502

These pellets were obtained from single lots.

The pellets required for extending the testing from 5 to 10 yr will be obtained from the dissected pyrogen igniters, which will provide 12 gm of the NMP-502 pellets and 6 gm of the 2070A pellets per igniter.

2. Preparation for Storage

a. Packaging and Identification

Pellet samples consisting of 40 gm each are placed in paper containers and stored in designated humidity cabinets. Samples will be stored without lids and will be individually identified with pellet type, entry and withdrawal dates, and temperature and humidity factors.

b. Initial Testing

To provide baseline data prior to storage, 40 gm of each type will be subjected to the entire test sequence described in paragraph 4. This pellet group will consist of 40 gm from each lot.

3. Storage

Storage of igniter pellets, in the types indicated in paragraph 1, will be in the environments as follows:

Temperature (^{o}F)	Humidity (% rh)
100	70
100	0
70	70
70	0

Withdrawals from storage for testing will be in accordance with Table 2-2.

4. Testing

a. Testing of Boron and Lead Chromate (2070A) Pellets

1) Heat-of-Explosion Test

The average calorific output of boron and lead chromate (2070A) pellets will be determined by using an adiabatic calibrated calorimeter. For each of eight determinations, 2 gm of pellets will be weighed to the nearest 0.1 mg and placed in the combustion capsule of the calorimeter. A 10 cm strip of Parr Wire, No. 45C10, or approved equivalent, will be connected across the terminals and passed through the pellets. The combustion chamber will be purged three times with inert gas at 25 atmospheres. The chamber will then be closed and pressurized to 25 atmospheres with inert gas. The samples will then be burned; the calorimetric value will be calculated in calories per gram; and each calorimetric determination will be recorded.

2) Impact Sensitivity Test

Using a Picatinny Arsenal Impact Test Apparatus No. RAPD 167354, the impact sensitivity of the pellets will be determined by subjecting individual pellets to the impact from a freely falling weight of 2 kg. The pellet will be placed in a steel die cup on an anvil and subjected to the impact of a weight falling from a predetermined height.

TABLE 2-2

IGNITER AND SAFE AND ARM PELLETS TEST SCHEDULE

Test No.	Sample Type	Zero Time Date*	Temp (°F)	RH (%)	Test Sequence (mo from zero time)**																			
					***	3	6	9	12	15	18	21	24	30	36	42	48	54	60	72	84	96	108	120
1	2070A	Sep 62	100	70	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a					
2	2070A	Sep 62	100	0		a	a	a	a	a	a	a	a	a	a	a	a	a	a					
3	2070A	Sep 62	70	70		a	a	a	a	a	a	a	a	a	a	a	a	a	a					
4	2070A	Sep 62	70	0		a	a	a	a	a	a	a	a	a	a	a	a	a	a					
5	NMP-502	Sep 62	100	70	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b					
6	NMP-502	Sep 62	100	0		b	b	b	b	b	b	b	b	b	b	b	b	b	b					
7	NMP-502	Sep 62	70	70		b	b	b	b	b	b	b	b	b	b	b	b	b	b					
8	NMP-502	Sep 62	70	0		b	b	b	b	b	b	b	b	b	b	b	b	b	b					
9	NMP-502	Feb 63	70	Amb									c		c		c		c	c	c	c	c	c
10	2070A	Feb 63	70	Amb									c		c		c		c	c	c	c	c	c

*Zero time = Receiving date

**Test Sequence:

a = gm sample withdrawn and tested in accordance with paragraph B.4.a.

b = gm sample withdrawn and tested in accordance with paragraph B.4.b.

c = gm sample withdrawn and tested in accordance with paragraph B.4.c.

***Initial time test (qualification test)

The height from which the weight will be dropped to provide a 50-percent probability of ignition of the pellet will be recorded.

3) Moisture Content Test

Moisture content testing will be conducted by using a 10-gm sample. The determination will be made by removing the samples from storage, and weighing, drying (at 150° F for 3 hr), and then reweighing them. The difference between the two weighings will then be recorded.

4) Vibration Resistance Test

The vibration resistance test will use a 6-gm ± 1-pellet sample. The pellets will be weighed and placed in a container (Figure 2-1) and vibrated for 90 min along one axis of the container at 36 cps at a double amplitude of 0.060 ± 0.002 in. peak-to-peak. After the vibration test, the sample will then be removed from the vibration tester and agitated 30 ± 1 sec on a U.S. Standard No. 40 mesh screen. The remaining material will be weighed, and the difference from the original weight recorded.

b. Testing of $BKNO_3$ Pellets

1) Heat-of-Explosion Test

The heat-of-explosion test for $BKNO_3$ pellets will be the same as described in paragraph 4.a.1) except for sample weight, which will be 1 gm.

2) Impact Sensitivity Test

The impact sensitivity test for $BKNO_3$ pellets will be conducted in the same manner as described in paragraph 4.a.2) for the 2070A pellets.

3) Moisture Content Test

Moisture content determination for $BKNO_3$ pellets will be the same as described in paragraph 4.2.3) for the 2070A pellets.

4) Vibration Resistance Test

Vibration resistance testing of $BKNO_3$ pellets will be conducted by using a 12-gm sample ±1 pellet. The sample will be weighed and placed in a vibration tester, as shown in Figure 2-2, and subjected to the same test described in paragraph 4.a.4).

c. Microscopic Examination

Pellets obtained from the dissected igniters will be examined microscopically and tested for hardness to observe any changes in

the surface of the pellets. An ignition study will be made in the pressurized Kopito furnace, or equivalent. This furnace can be pressurized to 300 to 400 psi, and at the same time the temperature can be raised very rapidly to 5000° to 6000° F. Using a calorimeter to measure the heat input, the changes in ignition properties of the aged pellets will be determined. The parameters to be measured in the ignition study are: (1) Energy to ignite pellets and (2) energy liberated from pellets. These are the probable parameters of failure of the pellets.

C. DATA EVALUATION

The data obtained from the heat-of-explosion impact, sensitivity, and moisture and vibration resistance tests will be plotted versus storage time and analyzed for trends. If trends develop in the data, they will be further analyzed for causes and reported. However, the results of testing will be used only for failure analysis, and no service life prediction will be made based on this data.

Data generated from the energy required for ignition and energy liberated from ignition of the pellets will be plotted. If degradation is noted, a suitable failure criteria will be required at that time.

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3. Storage

The TT A/D switches will be stored in HPC/B building No. 2152 at 80° F and 50 percent rh with the forward axis up to simulate operational conditions. The switches will be withdrawn from storage for conditioning and testing as scheduled in Table 2-3.

4. Periodic Conditioning and Inspection Testing

a. Transportation Vibration Testing

The switches will be subjected to transportation vibration during the periods indicated on Table 2-3. Designated switches will be mounted on a TT A/D switch vibration fixture, drawing No. SK-4-32-4871. Vibration will be conducted along each axis, as shown in Figure 2-4. Vibration will consist of the following:

(1) Amplitude: 3.5 G rms between 5 and 50 cps; vibration limited to 0.4 in. peak-to-peak.

(2) Range: 5 to 50 cps.

(3) Duration: two double sweeps (5 to 50 cps and return to 5 cps for each double sweep) at 1/2 octave per min in each of the three axes.

The test is designed to closely represent the actual conditions to which the missile is subjected in the field. The road test vibration data were analyzed, and the above requirements were determined to be more realistic than vibration requirements described in specification HPC 133-08-5-1C.

b. Visual Inspection

Prior to and after each vibration, a visual inspection will be made to determine the formation of corrosion and surface damage, such as loose or bent connector pins, dents, cracks, and safing window damage.

c. Electrical Tests

Prior to and after each environmental test, the TT A/D switch will be tested to determine A/D electrical continuity, cycle time, and circuit resistances according to the procedure for the particular switches as described in specification HPC 133-08-5-1C.

d. Mechanical Lock and Manual Disarm Test

With the A/D switch in the disarm position and the safing pin installed, removal of the safing pin by hand during application of 18 vdc to the arming circuit should not be possible. Any pin removal under these conditions shall constitute a failure.

TABLE 2-3

THRUST TERMINATOR SWITCH TEST SCHEDULE

Switch S/N	Zero Time Date*	Test Sequence (mo from zero time)**										
		0***	12	24	36	48	60	72	84	96	108	120
		Switch No. 7300-5										
OOAMA 1	Apr 63	b	b	b	b	b	c					
OOAMA 2	Apr 63	b	b	b	b	c						
EA6081	Apr 63	b	b	b	c							
EA6041	Apr 63	b	b	c								
EA6193	Apr 63	b	c									
OOAMA 3	Apr 63	b		b		c						
OOAMA 4	Apr 63	b					c					
OOAMA 5	Apr 63	b				c						
OOAMA 6	Apr 63	b			c							
EA6066	Apr 63	b		c								
EA6196	Apr 63	b	c									
		Switch No. 7300-9										
OOAMA 7	Jul 63	b	b	b	b	b	c					
OOAMA 8	Jul 63	b	b	b	b	c						
EA6222	Jul 63	b	b	b	c							
EA6205	Jul 63	b	b	c								
EA6228	Jul 63	b	c									
OOAMA 9	Jul 63	b		b		c						
OOAMA 10	Jul 63	b					c					
OOAMA 11	Jul 63	b				c						
EA6224	Jul 63	b			c							
EA6216	Jul 63	b		c								
EA6243	Jul 63	b	c									

Note: OOAMA switches, S/N 1 thru 11, have not been received as of 1 Jul 66.

*,**,***See end of table for legend

TABLE 2-3 (Cont)

THRUST TERMINATOR SWITCH TEST SCHEDULE

Switch S/N	Zero Time Date*	Test Sequence (mo from zero time)**										
		0***	12	24	36	48	60	72	84	96	108	120
		Switch No. 7300-11										
EA1797	Apr 65	b	b	b	b	b	b	b	b	b	b	c
EA1798	Apr 65	b	b	b	b	b	b	b	b	b	c	
EA1799	Apr 65	b	b	b	b	b	b	b	b	c		
EA1800	Apr 65	b	b	b	b	b	b	b	c			
EA1801	Apr 65	b	b	b	b	b	b	c				
EA1802	Apr 65	b	b	b	b	b	c					
EA1803	Apr 65	b	b	b	b	c						
EA1804	Apr 65	b	b	b	c							
EA1805	Apr 65	b	b	c								
EA1806	Apr 65	b	c									
EA1820	Apr 65	b		b		b		b		b		c
EA1821	Apr 65	b		b		b		b		c		
EA1822	Apr 65	b		b		b		c				
EA1823	Apr 65	b		b		c						
EA1824	Apr 65	b										c
EA1825	Apr 65	b									c	
EA1826	Apr 65	b								c		
EA1827	Apr 65	b							c			
EA1828	Apr 65	b						c				
EA1829	Apr 65	b					c					
EA1876	Jul 65	b				c						
EA1877	Jul 65	b			c							
EA1878	Jul 65	b		c								
EA1879	Jul 65	b	c									

* Receiving date

** Test Sequence:

b = Transportation vibration and inspection testing

c = Final conditioning and destruct testing

*** Initial time test

Note: All TT switches stored at 80° F and 50 percent rh

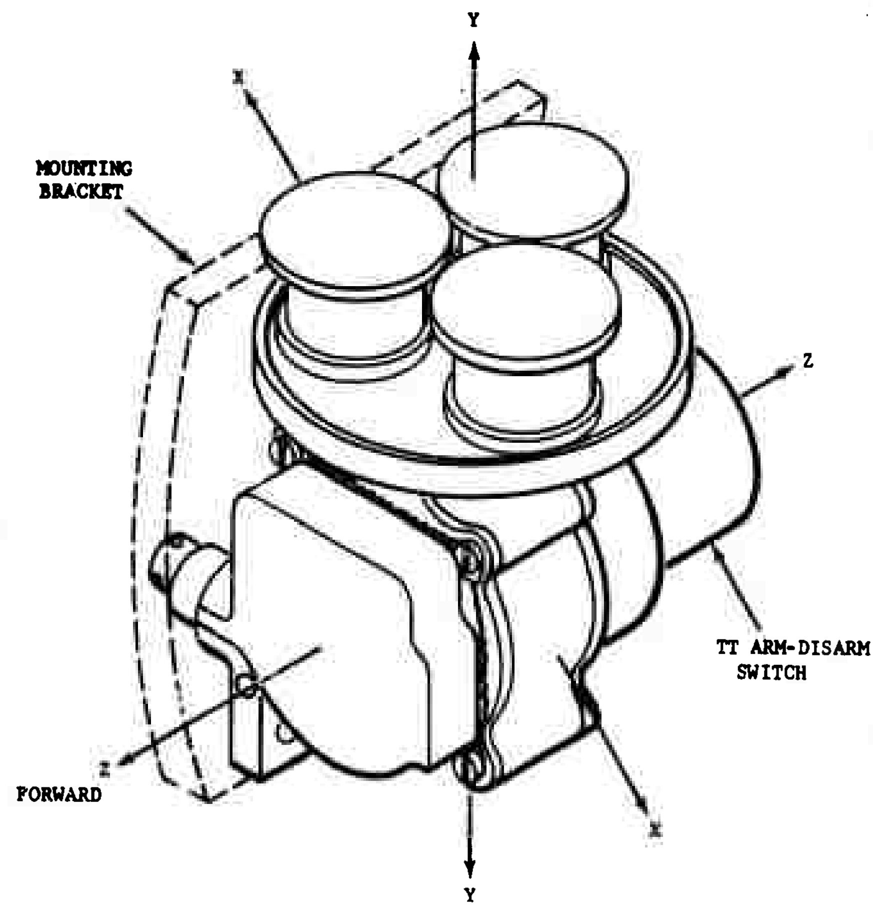

Figure 2-4. Arm-Disarm Switch Vibration Axes

With the safing pin removed, the A/D switch will indicate the armed position upon application of 18 vdc to the arming circuit. The A/D switch will be manually disarmed by installing the safing pin and checking the visual indicator for disarmed condition. The entire letter S shall appear in the window. This test will be conducted prior to and after vibration tests as described in specification HPC-133-08-5-1C.

5. Final Conditioning

a. Simulated Flight Environment

1) Operational Vibration

The operational vibration phase of simulated flight environment for the A/D switch shall consist of simultaneous application of random vibration and the equivalent pressure of 90,000 ± 4,000 ft altitude. The temperature requirements as specified in paragraphs 3.5.2.2 and 4.5.11 of specification HPC-133-08-5-1C will not be required for this test. The vibration axis shall be changed every 2 cycles.

Flight vibration conditions shall be simulated as specified in paragraphs 3.5.2.2 and 4.5.11 of specification HPC-133-08-5-1C, Thrust Termination, Arm-Disarm Switch. Firing circuits will be continuously monitored during the simulated flight environment to determine contact closure and circuit continuity. Conditions which do not conform to paragraphs 3.4.18 and 3.4.19 of specification HPC-133-08-5-1C will be recorded. Monitoring current should not exceed 500 ma for this test.

2) Acceleration Conditioning

The A/D switch shall be mounted on a centrifuge, or equivalent, using the normal mounting provisions of the unit. The switch will be tested by applying an acceleration force as required in specification HPC-133-08-5-1C, paragraph 3.5.2.1. The electrical circuits will be monitored during acceleration for contact chatter and excessive rotor bounce, as defined in HPC-133-08-5-1C, paragraphs 3.4.18 and 3.4.19. Monitoring current shall be 500 ma.

b. Rotor Bounce Test

The rotor bounce test shall be conducted during the transportation vibration conditioning sequence in accordance with specification HPC-133-08-5-1C.

c. Hermetic Seal Test

The hermetic seal test shall be conducted after completion of the operational vibration conditioning in accordance with specification HPC-133-08-5-1C.

d. Insulation Resistance Test

The insulation resistance between all mutually insulated parts shall be measured at a potential of 100 to 500 vdc, inclusive. Insulation resistance less than 100 megohms shall constitute a failure.

e. Dielectric Strength Test

A limit of 500 vdc shall be applied by increasing the voltage from 0 to 500 vdc at a maximum rate of 100 vdc per sec between all mutually insulated leads and between the leads and the enclosing case. The 500 vdc will be maintained not less than 1 min. Any arc-over breakdown or current flow which constitute a failure as detailed in specification HPC 133-08-5-1C.

f. Cycle Test

The switches will be cycled after tests a. through e. are completed. The cycle test will be conducted in accordance with specification HPC-133-08-5-1C, paragraph 4.5.13. The total cycles a switch will receive before disassembly is 500.

6. Destruct Testing

Upon completion of the 500 cycles or failure of a unit, several areas on the A/D switch shall be examined microscopically to determine the extent of wear or stress failure. The face of the wiper will be examined for peeling, cracking, and contact wear. The area where the contact is soldered will be examined to determine undesirable alloying with the solder. The motor will also be visually examined for wear.

C. DATA EVALUATION

1. Performance Tests

The data obtained from the firing circuit resistance tests will be used in conjunction with appropriate specification limits to predict the service life of the A/D switch. A regression analysis will be made using the individual data points. Extrapolation of the regression curve will establish the service life value.

2. Attribute Tests

The observed condition of switches which received a total of 500 cycles and the results of the hermetic seal, rotor bounce, and dielectric tests will be recorded. Data obtained from measurable parameters will be plotted and analyzed for trends. The use of the above data will be limited to failure analysis investigations.

TABLE 2-9

FRANGIBLE SECTORS TEST SCHEDULE, WING II
(Storage Conditions at 100° F)

Sector Ser No. 10% rh	Storage Date	Zero Time Date**	Sector Ser No. 70% rh	Zero Time Date**	Test Sequence (mo from zero time)* 0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
1338	Jun 63	Nov 62	1251	Nov 62	a		c																		
1364	Jun 63	Nov 62	1260	Nov 62																					
1379	Jun 63	Nov 62	1281	Nov 62																					
1456	Jun 63	Nov 62	1300	Nov 62																					
1365	Jun 63	Nov 62	1252	Nov 62	a		b		c																
1380	Jun 63	Nov 62	1262	Nov 62																					
1470	Jun 63	Nov 62	1283	Nov 62																					
1505	Jun 63	Nov 62	1302	Nov 62																					
1254	Jun 63	Nov 62	1284	Nov 62	a		b		b		c														
1265	Jun 63	Nov 62	1305	Nov 62																					
1287	Jun 63	Nov 62	1350	Nov 62																					
1306	Jun 63	Nov 62	1366	Nov 62																					
1316	Jun 63	Nov 62	1383	Nov 62	a		b		b		b		c												
1337	Jun 63	Nov 62	1477	Nov 62																					
1360	Jun 63	Nov 62	1525	Nov 62																					
1378	Jun 63	Nov 62	1700	Nov 62																					
1449	Jun 63	Nov 62	1740	Nov 62	a		b		b		b		b		c										
1538	Jun 63	Nov 62	1783	Nov 62																					
1696	Jun 63	Nov 62	2003	Nov 62																					
1739	Jun 63	Nov 62	2110	Nov 62																					
1782	Jun 63	Nov 62	2126	Nov 62	a		b		b		b		b		b		c								
1991	Jun 63	Nov 62	2235	Nov 62																					
2030	Jun 63	Nov 62	1253	Nov 62																					
2048	Jun 63	Nov 62	1264	Nov 62																					
2107	Jun 63	Nov 62	1280	Nov 62	a		b		b		b		b		b		b		c						
2114	Jun 63	Nov 62	1299	Nov 62																					
2136	Jun 63	Nov 62	1317	Nov 62																					
2143	Jun 63	Nov 62	1361	Nov 62																					
1386	Jun 63	Nov 62	1324	Nov 62			b		b		b		b		b		b		b		c				
1618	Jun 63	Nov 62	1368	Nov 62																					
1736	Jun 63	Nov 62	1385	Nov 62																					
1763	Jun 63	Nov 62	1616	Nov 62																					
1277	Jun 63	Nov 62	1732	Nov 62			b		b		b		b		b		b		b		b		c		
1326	Jun 63	Nov 62	1753	Nov 62																					
1371	Jun 63	Nov 62	1803	Nov 62																					
1811	Jun 63	Nov 62	2061	Nov 62			b		b		b		b		b		b		b		b		b		c
2140	Jun 63	Nov 62	1276	Nov 62																					
2083	Jun 63	Nov 62	1276	Nov 62																					

*Test Sequence
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing

**Zero time is manufacture date

***Initial time test

3. <u>Transportation Vibration</u>

Transportation vibration of the frangible sector will be accomplished by mounting the sector assembly on the frangible sector vibration fixture, and vibrated as follows:

(a) Amplitude: 3.5 G rms between 5 to 50 cps; vibration limited to 0.4 in. peak-to-peak

(b) Range: 5 to 50 cps

(c) Duration: two double sweeps (5 to 50 cps and return to 5 cps for each double sweep) at 1/2 octave per minute in each of the three axes.

Note

All transportation vibration performed at zero time was in accordance with the qualification testing requirements as specified in Hercules Specification HPC-133-08-5-2A, <u>Frangible Sector Assembly</u>, paragraph 4.5.9. However this testing, when used during the testing sequences, would expose each frangible sector to vibration cycling in excess of that received by operationally deployed units. The vibration requirements shown above are considered a more realistic test.

4. <u>Final Conditioning and Testing</u>

a. <u>Simulated Flight Vibration</u>

The operational vibration for the frangible sector will consist of random vibration. The vibration axis shall be changed every 2 cycles. Flight altitude conditions will be simulated as follows:

(1) The frangible sector shall be installed in an enclosure simulating the TT port and mounted on the vibration table.

(2) Flight vibration conditions shall be simulated as specified in HPC-133-08-5-2, <u>Frangible Sector Assembly</u>, paragraph 4.5.11.

b. <u>High Temperature Test</u>

One Wing I and one Wing II frangible sector from each environment will be subjected to high-temperature testing to simulate flight heating. The units will be placed in a temperature chamber and subjected to a temperature of 250° F for a maximum of 10 min. They will then be inspected for

physical damage and detonated in accordance with the functional test described in paragraph c. Data obtained from explosive testing of these ordnance components will be distinguished from that obtained from units not receiving the high temperature testing. Thus, any changes that may have developed as a result of this test will be apparent.

c. Functional Test

All frangible sectors, upon completion of their storage life, will be subjected to the Explosive Brisance Test. Testing will be conducted by placing the unit in a test fixture, checking the circuit continuity, and recording the bridgewire resistance. The assembly shall then be fired as described in specification HPC-133-08-5-2A, paragraph 4.5.8. Testing will be conducted at ambient conditions. Total function time and initiation current shall be recorded. The fragments of the sector shall be poured into a No. 3 screen, which is nested on a No. 6 screen above a No. 10 screen. The contents of each screen and those fragments that pass the No. 10 screen will be weighed in milligrams and the weights recorded. Photographs of the remaining fragments will be taken.

d. Visual Examination

A metallurgical analysis will be conducted on the fragments of the frangible sectors to determine possible changes in grain structure which affect performance of the sectors.

C. DATA EVALUATION

The data gained from the function time and bridgewire resistance tests will be used to predict service life of the frangible sectors. Regression analysis will be performed on the data and extrapolated to the applicable specification limit.

The remaining information obtained will be used for failure analysis.

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TABLE 2-11

NOZZLE CONFIGURATION

Applicable Wing No.	Nozzle Ser No.	Drawing No.	Vendor*	FTM Configuration	Expansion Ratio
I	0582	6224/5710**	KAE	PFRT	6:1
I	0583	6224/5710**	KAE	PFRT	6:1
I	0584	6224/5710**	KAE	PFRT	6:1
I	0585	6224/5710**	KAE	PFRT	6:1
I	0956	6354-4	KAE	414-420	6:1
I	0957	6354-4	KAE	414-420	6:1
I	0958	6354-3	KAE	414-420	6:1
I	0959	6354-3	KAE	414-420	6:1
I	0994	01S00659-8	KAE	PFRT	18:1
I	0995	01S00659-7	KAE	PFRT	18:1
I	5102	6354-1	TRW	408-413	18:1
I	5103	6354-1	TRW	408-413	18:1
I	5104	6354-1	TRW	408-413	18:1
I	5105	6354-1	TRW	408-413	18:1
I	5106	6354-1	TRW	408-413	18:1
I	5107	6354-1	TRW	408-413	18:1
II	5156	01A00768	TRW	Operational	18:1
II	5158	01A00768	TRW	Operational	18:1
II	5152	01A00768	TRW	Operational	18:1
II	5151	01A00768	TRW	Operational	18:1
II	5155	01A00768	TRW	Operational	18:1
II	5167	01A00768	TRW	Operational	18:1
II	5153	01A00768	TRW	Operational	18:1

*Vendor: KAE = Kaiser Aerospace and Engineering
TRW = Thompson-Ramo-Wooldridge, Inc.

**Nozzle utilized an approach section, drawing No. 6224, and an exit section, drawing No. 5710

TABLE 2-12

NOZZLE TEST SCHEDULE

Nozzle Ser No.	Zero Time Date*	Test Sequence (mo from zero time)**																				
		0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
0582	Jan 63	a	d	d	d	d	d	dc														
0583	Jan 63	a	d	d	d	d	d	d	d	dc												
0584	Jan 63	a	d	d	d	d	d	d	d	d	d	dc										
0585	Jan 63	a	d	d	d	d	d	d	d	d	d	d	d	dc								
0956	Jan 63	a	d	d	d	d	d	d	d	d	d	d	d	d	d	dc						
0957	Jan 63	a	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	dc				
0958	Jan 63	a	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	dc		
0959	Jan 63	a	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	dc
0994	Jan 63	a		a		a		a		a		a		a		a		a		a		ac
0995	Jan 63	a		a		a		a		a		a		a		a		a		a		ac
5102	Jan 63	a	ab	ab	ab	ab	ab	ab	at	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	abc
5103	Jan 63	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	ac
5104	Jan 63	a		ab		ab		ab		ab		ab		ab		ab		ab		ab		abc
5105	Jan 63	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	abc
5106	Jan 63	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	ac
5107	Jan 63	a		ab		at		ab		ab		ab		ab		ab		ab		ab		abc
5156	Dec 64					d	d	d	d	dc												
5158	Dec 64					d	d	d	d	d	d	dc										
5152	Dec 64					d	d	d	d	d	d	d	d	dc								
5151	Dec 64					d	d	d	d	d	d	d	d	d	d	dc						
5155	Dec 64					d	d	d	d	d	d	d	d	d	d	d	d	dc				
5167	Dec 64					d	d	d	d	d	d	d	d	d	d	d	d	d	d	dc		
5153	Dec 64					d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	dc

* Assembly date
** Test Sequence:
a = Perform inspection test
b = Perform conditioning sequence
c = Perform final inspection (includes disassembly and X-ray)
d = Hand actuate and perform visual inspection

b. Pressure Leak Test

The pressure leak test is performed by placing the nozzle assembly in a special fixture that seals the approach and exit cone sections. Nitrogen gas is induced into the approach section at the rate of 2-1/2 psi/sec. A check for leaks at the split line area, utilizing leak-tec, is performed while each nozzle is subjected to 50 psi internal pressure. This compound is designed to detect various size leaks by readily visible formation of bubbles at the location of the leak. The pressure is then increased to 200 psi, stabilized for a minimum of 60 sec, and isolated and allowed to decay through the carbon core in the nozzle throat. The pressure drop is recorded at the 1-min, 2-min, 5-min, and 10-min time interval. This test is performed in accordance with HD-2-1-4903.

c. Cold Torque Test

The cold torque test is performed using a special cold torque testing device employed on full scale motors according to OI-02-1-14, Revision 4. The breakaway torque and the torque required to vector 4° right and 4° left is recorded.

d. Radiographic Inspection

Radiographic inspection is performed in accordance with specification HPC-133-02-5-2A.

4. Conditioning Sequence

The conditioning sequence is performed in the same fixture as the pressure test, at the intervals shown in Table 2-12. A motorized cycling apparatus is mounted to the nozzle by the use of the NCU pad and actuator bracket. The nozzle is cycled from 4° right to 4° left at a rate of 60 cpm for a maximum of 400 cycles per test period.

5. Final Inspection Test

Upon completion of the scheduled storage period, the nozzles will be X-rayed, disassembled, and given a complete visual inspection to determine wear on mating surfaces and O-ring compression set, corrosion, and other possible aging effects. Components will be photographed upon disassembly.

6. Hand Actuation

Sea-level-type nozzles will be hand cycled approximately 4° right and 4° left without removing the nozzle from storage.

C. DATA EVALUATION

A regression analysis will be performed on the data obtained from the breakaway cold torque and pressure tests. If a trend should develop indicating degradation, a suitable failure criteria will be established at that time. The data obtained from the remaining tests and inspections will be used for failure analysis. The cold torque data obtained from nozzles on surveillance full scale motors will be compared to component data.

SECTION VI

SPIRALLOY SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The two types of Spiralloy to be studied are identified in Table 2-13 by the glass and resin used, the general motor configuration each type is associated with, and the test specimen used.

TABLE 2-13

SPIRALLOY TYPE IDENTIFICATION

Test Specimen	Glass	Glass Finish	Resin	General Associated Motor Config.
Layer lap shear	Owens-Corning SCG-155-12 (S-994)	HTS	Union Carbide ERLA 2256	Wings II-VI
Wafer lap shear				
Wafer bottles				
Short beam shear				
NOL tensile rings				
12-in. ovaloid bottles	Owens-Corning SCG-155-12 (S-994)		Union Carbide ERLA 2256	Wings II-VI
Layer lap shear Short beam shear	Owens-Corning E Glass		Shell Epon 826 CL	Wing I
FSU case Hydroburst	Owens-Corning E Glass	HTS	Shell Epon 826 CL	Wing I

There have been a wide variety of tests employed as a result of test improvements made since the program was initiated in March 1961. The interlaminar shear (ILS) test was the only available test at the time the Wing I program was initiated. (See Appendix A, Section II.) The 2.6-in. ILS tubes give scattered data and are affected by such variables as resin content and exposed roving ends. Also, the ILS tube is not a pure shear specimen. Bending is induced into the specimen due to slightly eccentric loading. The short beam shear and the hoop tensile tests were made available during the Wing II development program and, because of their superiority over the ILS test, were subsequently incorporated into the surveillance

program. The short beam shear test is theoretically a pure shear test (on a flat specimen made from isotropic material). When anisotropic materials such as filament-wound fiberglass are used, directional and nonuniform properties come into consideration. Resin contents, fiber orientations, and different elastic properties in tension and compression affect results.

The 12-in. ovaloid bottle was included in the Wing II Spiralloy test program to obtain biaxial failure data and to verify the results of the short beam shear and the hoop tensile tests. The use of the ovaloid bottle is questionable for comparative data, since there is a difference in the mode of failure of the short beam and the 12-in. bottle. The 12-in. bottle provides a sample that more closely represents the storage conditions of the case and provides a more representative regression curve than the shear and tensile laboratory samples.

The lap shear and the wafer shear tests, to be used for future Spiralloy testing, will provide shear values which can be used in a case stress analysis. Additional advantages of the lap shear and wafer shear specimens are as follows:

(1) Differences in resin content and elastic properties do not affect results.

(2) Lap shear specimens can be obtained from aged FSU cases without significant variations due to outside influences.

(3) The wafer shear specimen more accurately simulates the Wing II case mode of failure.

The 12-in. wafer bottle will be included to obtain verification and correlation of the layer lap shear and wafer lap shear tests.

In order to supplement the questionable ILS data presently available for use in predicting Wing I service life values, reject and excess Wing I cases will be hydroburst. A description of these are given in Table 2-14.

B. DETAILED TEST PLAN

1. <u>Sample Acquisition</u>

The short beam shear and NOL rings were manufactured by Bacchus under laboratory conditions. Eight layer lap shear cylinders, twenty-one wafer lap shear cylinders, and thirty wafer bottle samples will be manufactured at Hercules' Clearfield, Utah, plant and machined to specimen size at Bacchus. The FSU cases to be hydroburst, or cut up for lap shear specimens, were manufactured by Rocky Hill and Black, Sivalls, and Bryson, Ardmore, Oklahoma. The 12-in. ovaloid bottles were manufactured by Rocky Hill.

TABLE 2-14

CASE CONFIGURATION SUMMARY

Case No.	Dwg No.	Date of Mfr	Glass Type	Resin Type	Discrepancies When Assigned to Program
BB0152	8062	Dec 62	HTSE	826	None
BB0156	8062	Jan 63	HTSE	826	None
BB0162	8062	Jan 63	HTSE	826	None
BB0164	8062	Jan 63	HTSE	826	None
BB0170	8062	Jan 63	HTSE	826	None
BB0172	8062	Jan 63	HTSE	826	None
BB0175	8062	Jan 63	HTSE	826	None
BB0176	8062	Jan 63	HTSE	826	None
BB0180	8062	Feb 63	HTSE	826	None
BB0181	8062	Feb 63	HTSE	826	None
R206X.13	3267	Feb 62	HTSE	826	None
R205X.18	3267	Jan 62	HTSE	826	Aft ring out of tolerance
X295X.20	3267	Jan 62	HTSE	826	None
R205X.62	8062	Jan 62	HTSE	826	Raceway un-bonded
T402.35	3267	Nov 60	801E	828	None
Q206.60	3267	Nov 61	801E	828	Cracked phenolic
HP 00253	01A00221	Jan 64	S994	2256	None
HP00026	01A00221	Apr 63	S994	2256	Loose glass at at "Y"
P120Y.03	01A00221	Oct 62	S994	2256	None
P120Y.04	01A00221	Oct 62	S994	2256	None

2. Sample Preparation

Whenever possible, the Spiralloy material will be placed in storage in sample size; then prior to testing, the samples will be machined to proper specimen configuration. This will prevent excessive exposure of end-cut glass roving to humidity.

The samples and specimens will be serialized for identification. Tests will be conducted on the various specimens, as shown in Tables 2-15 and 2-16 prior to storage. The data obtained will be used as a baseline, and all subsequent test data will be compared with it to show any trends which may develop.

Material used for winding test specimens, Santa Clara 994 glass roving, ERL 2256 epoxy resin, and MPD Hardener, will be 100 percent inspected upon receipt and after completion of cylinder or vessel winding for all parameters as required in Minuteman material specifications HPC-133-08-2-15 and HPC-133-08-2-3. The materials used will meet the acceptance requirements of these specifications. In addition to specification acceptance testing, the following materials inspections will be made:

(a) Roving

(1) Characterization of finish by Pyrolysis technique

(2) Initial and periodic Clycol analysis of finish on roving

(b) Resin

(1) Characterization of each barrel of resin to be used by gas chromatography techniques

(2) Characterization of each barrel of resin to be used by refractive index techniques

(3) Periodic check of the resin stored in barrels for moisture content

(c) Hardener

(1) Characterization of each barrel of hardener by refractive index technique

(2) Periodic check of moisture content of each barrel of hardener

TABLE 2-15

SPIRALLOY TEST SCHEDULE

Test	Storage Conditions		Appli-cable Wing No.	Zero Time Date*	Test Sequence (mo from zero time)																					
	Temp (°F)	RH (%)			0	3	6	9	12	15	18	21	24	27	30	33	36	42	48	54	60	72	84	96	108	120
Wafer lap shear, Type I (cyl)	60	0	II-VI	Mar 66					4**				4				4		4		4	4	4	4	4	4
		Amb	II-VI	Mar 66					4				4				4		4		4	4	4	4	4	4
		70	II-VI	Mar 66					4				4				4		4		4	4	4	4	4	4
	80	50	II-VI	Mar 66					4				4				4		4		4	4	4	4	4	4
	100	Amb	II-VI	Mar 66					4				4				4		4		4	4	4	4	4	4
		35	II-VI	Mar 66					4				4				4		4		4	4	4	4	4	4
		70	II-VI	Mar 66					4				4				4		4		4					
Layer lap shear, Type I (cyl)	60	0	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		Amb	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		70	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
	80	50	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
	100	Amb	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		35	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		70	II-VI	Mar 66			4		4		4		4		4		4	4	4	4	4					
Wafer lap shear, Type I w/mat (cyl)	60	0	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
		Amb	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
		70	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
	80	50	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
	100	Amb	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
		35	II-VI	May 66					4				4				4		4		4	4	4	4	4	4
		70	II-VI	May 66					4				4				4		4		4					
Layer lap shear, Type II (cyl)	60	0	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		Amb	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		70	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
	80	50	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
	100	Amb	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		35	II-VI	May 66			4		4		4		4		4		4	4	4	4	4	4	4	4	4	4
		70	II-VI	May 66			4		4		4		4		4		4	4	4	4	4					
Wafer bottle hydroburst	80	50	II-VI	Feb 66					3				3				3		3		3	3	3			
Ovaloid bottle hydroburst	80	50	II	May 63	10		5		5		5		5		5		5									
Short beam shear (Laboratory samples)	80	0	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	80	35	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	80	70	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	100	70	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

*Zero time date is fabrication date

**Numbers indicate specimens tested

TABLE 2-15 (Cont)

SPIRALLOY TEST SCHEDULE

Test	Storage Conditions: Temp (°F)	Storage Conditions: RH (%)	Applicable Wing No.	Zero Time Date*	Test Sequence (mo from zero time): 0	3	6	9	12	15	18	21	24	27	30	33	36	42	48	54	60	72	84	96	108	120
Coated NOL tensile rings	80	50	VI	Jul 65	8**		8		8		8		8		8		8		8		8					
Uncoated NOL tensile rings	80	0	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	80	35	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	80	70	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	100	70	II-IV	Sep 63	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

*Zero time date is fabrication date

**Numbers indicate specimens tested

TABLE 2-16

FULL-SCALE UNIT CASE TEST SCHEDULE

Case No.	Applicable Wing No.	Storage Conditions Temp (°F)	Storage Conditions RH (%)	Zero Time Date*	Type Test Performed	Test Sequence (mo from zero time)** 24	30	36	42	48	54	60	72	84	96	108	120
BB0156	I	80	50	Jan 63	LS & SBS***			b		b		b		b			
BB0164	I	80	50	Jan 63	LS & SBS			b			b		b		b		
BB0180	I	80	50	Feb 63	LS & SBS			b				b			b		b
BB0152	I	80	50	Dec 62	Hydroburst	a											
BB0162	I	80	50	Jan 63	Hydroburst LS & SBS			ab									
R206X.13	I	80	50	Feb 62	Hydroburst LS & SBS					ab							
R205X.62	I	80	50	Jan 62	Hydroburst LS & SBS							ab					
R205X.20	I	80	50	Jan 62	Hydroburst LS & SBS								ab				
[illegible]	I	80	50	Jan 62	Hydroburst LS & SBS						ab						
[illegible]	II	80	50	Jun 64	LS & SBS	c	c	c	c	c	c	c	c				
[illegible]	II	80	50	Feb 63	LS & SBS		c	c	c	c	c	c	c	c			
P120Y.03	II	72	Amb	Oct 62	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
P120Y.04	II	72	Amb	Oct 62	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0170	I	72	Amb	Jan 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0172	I	72	Amb	Jan 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0175	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										

*,**,*** See end of table for legend

TABLE 2-16 (Cont)

FULL-SCALE UNIT CASE TEST SCHEDULE

Case No.	Applicable Wing No.	Storage Conditions		Zero Time Date*	Type Test Performed	Test Sequence (mo from zero time)**											
		Temp (°F)	RH (%)			24	30	36	42	48	54	60	72	84	96	108	120
BB0176	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0181	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
T402.35	PFRT	72	Amb	Nov 60	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
Q206.60	PFRT	72	Amb	Nov 61	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										

*Zero time date is date of fabrication

**Test Sequence:
a - Hydroburst
b - Cut, machine, and test LS & SBS specimens (8 ea)
c - Cut, machine, and test LS & SBS specimens (4 ea)

***LS - Lap shear cut from cases

***SBS - Short beam shear cut from cases

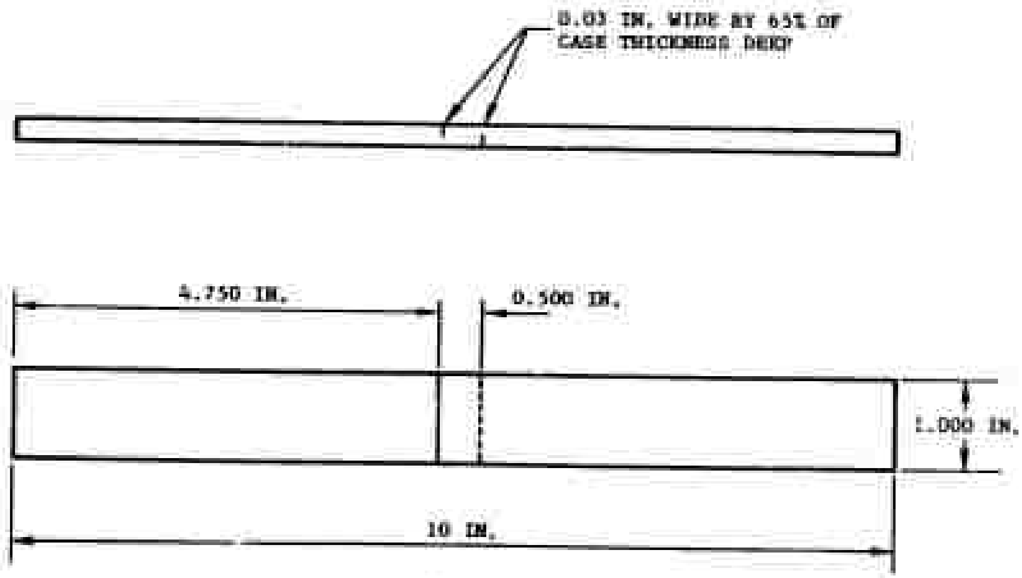


Figure 2-11. PSU Case Lap Shear Specimen

d. Wafer Pressure Vessels

The 12-in.-dia dome-to-dome wafer test vessels (Figure 2-12) were fabricated in accordance with drawing 12Z00524 and placed in environmental storage at 80° F and 50 percent rh. The wafer vessels are removed from storage and tested as scheduled in Table 2-15.

e. Ovaloid Pressure Vessels

The 12-in.-dia dome-to-dome ovaloid test vessels (Figure 2-13) were fabricated in accordance with Hercules drawing 2362 RN and placed in environmental storage at 80° F and 50 percent rh. The ovaloid vessels are removed from storage and tested as scheduled in Table 2-15.

3. Storage

The Spiralloy specimens are stored at Bacchus without protective wrapping and are subjected to the various environmental conditions shown in Table 2-15. The specimens are stored in desiccator cabinets containing a humidifier to maintain the desired humidity. Temperature is controlled by the building temperature control unit. The coated NOL rings (72 specimens) were fabricated and the edges coated with 2256 resin prior to placing them in environmental storage. FSU cases, 36-in. cylinders used for lap shear and short beam shear studies, were cut into sample sections, coated along exposed edges, and placed in environmental storage. Wing I hydroburst cases will be stored in a controlled environment, and Wing II and backup hydroburst cases will be stored under store house conditions (72° F, amb rh).

4. Testing

The material to be tested will be removed from storage after proper intervals and tested as described in the following subparagraphs.

a. NOL Tensile Test

The NOL rings will be tested for hoop tensile strength in accordance with Standard Operating Procedure HPC-050-03-13-46, using a Baldwin Testing Machine to apply a constantly increasing pulling force to semicircular segments until failure. Following the hoop tensile strength tests, the resin-to-glass ratio will be determined in accordance with Bacchus Laboratory Procedure, Section V, Method 7.

b. Short-Beam-Shear Test

One NOL uncoated ring will be withdrawn from storage each test period and cut into eight short-beam-shear specimens. (See Figure 2-6.) Eight specimens will be cut from an FSU case sample section each test period. The test will be conducted in accordance with Bacchus Laboratory Procedure Section III, Method 34, at a rate of 0.10 in. per min. The maximum force at failure will be recorded as shear strength.

c. Lap Shear

Two varieties of lap-shear tests will be conducted using five types of specimens. The first variety, designated as layer-lap-shear, will require three specimen configurations. These specimens will permit measurement of shear strength between the 14° helical-wound layer and the level-wound layer, and between the 14° helical-wound layers cut from the 36-in. sample cylinders. The shear strength between the 14° helical-wound layers will also be determined from specimens cut from FSU cases. The second test variety, designated as wafer-lap-shear, will require two specimen configurations for measuring the shear strength between 14° helical-wound layers and B-stage wafers. One specimen will allow shear of filaments oriented approximately parallel to the shear force and the other perpendicular to the shear force. The above specimens will simulate the possible case failure modes. Testing will be conducted on a Baldwin Tensile Test Machine using appropriate adapters, as shown in Figure 2-14. The dimensions of the lap-shear specimens and the method by which they are obtained from the sample cylinders are shown in Figures 2-9 and 2-10.

The third type of layer-lap-shear specimens will be obtained from rejected Wing I and Wing II cases. The specimens will be cut parallel to the longitudinal axis of the case to minimize the effect of curvature. (See Figure 2-8.) The cases to be used are given in Table 2-14. Three Wing I and three Wing II FSU cases are to be cut up for this study. Eight specimens will be machined from an FSU sample section during each test period. (See Table 2-16 and Figures 2-8 and 2-11.)

d. Wafer Pressure Vessels and 12-in. Ovaloid Bottles

The 12-in.-dia, dome-to-dome wafer vessels (Figure 2-12) and the 12-in. ovaloid bottles (Figure 2-13) will be instrumented with strain gages and hydroburst. Pressurization rate will be 50 psi/sec to burst. High-speed movies will be taken during the burst tests to define the area of failure initiation. Fifteen wafer vessels will be hydroburst in the Spiralloy Failure Criteria Study, and these results will be used as base time data for this study. Following the hydroburst test, each wafer vessel will be analyzed in accordance with Bacchus Laboratory Procedure, Section V, Method 7, to determine the resin-to-glass ratio.

e. Full Scale Unit Cases

The FSU cases will be hydroburst after storage periods, as indicated by the scheduled test dates in Table 2-16. The hydroburst procedure to be used will be the same as the Qualification Program for that particular case configuration. High-speed movie coverage will be obtained to determine the area of failure initiation. Volume determination will also be made for each FSU case during hydroburst. Cases will be instrumented with flexagages on the aft dome per Figure 2-15 and with strain gages on the cylindrical section per Hercules drawing 12S00402. This instrumentation will be used to record strains on the case during the hydroburst test.

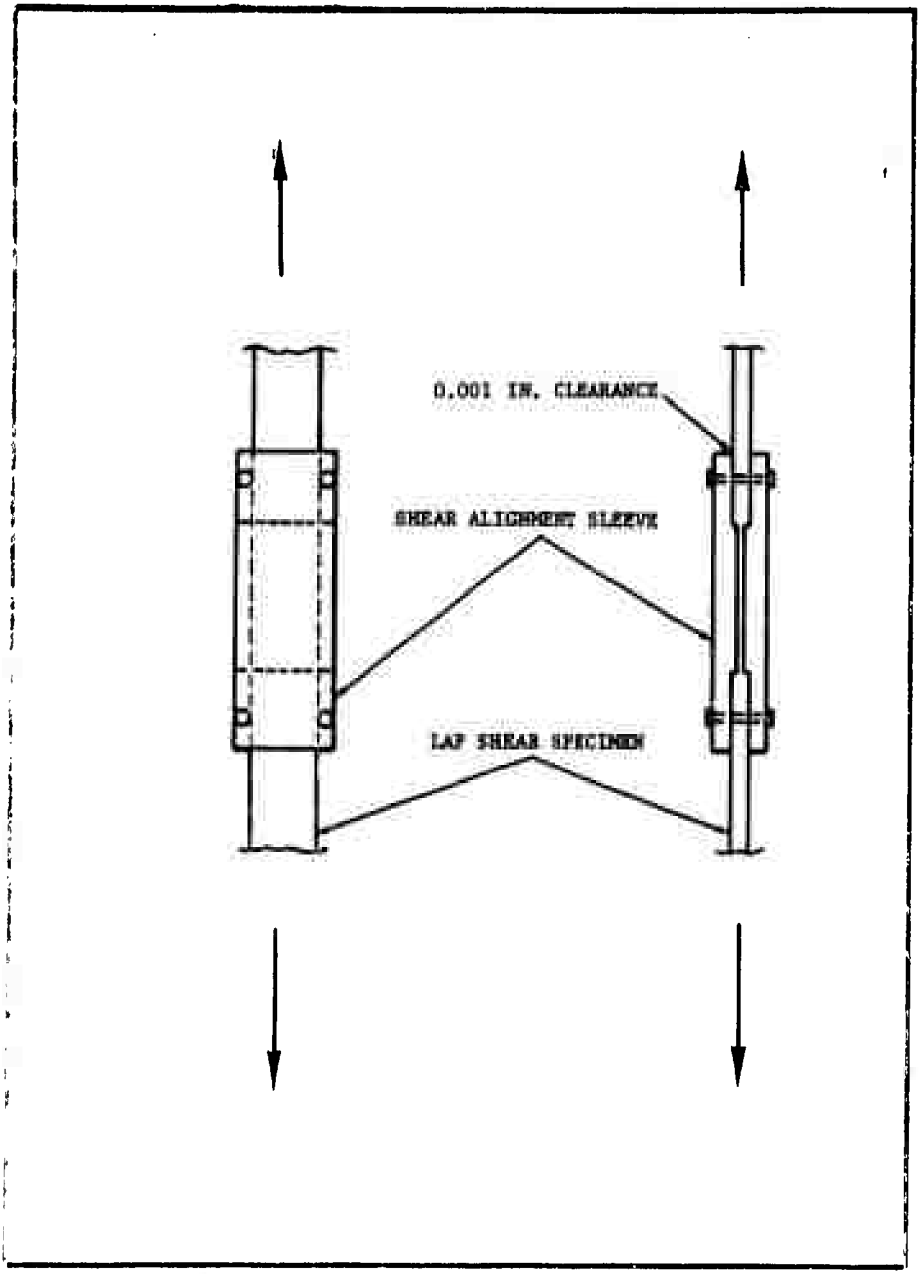


Figure 2-14. Lap Shear Test Arrangement

C. DATA EVALUATION

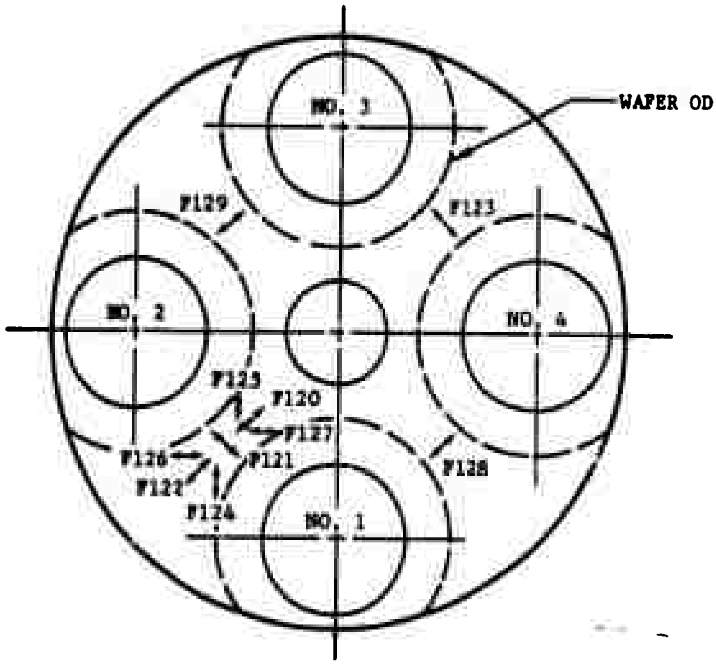
The Spiralloy data will be evaluated to determine the service life of Wings I through VI cases, and temperature and humidity effects on the degradation rate.

(1) The Wings II through VI Spiralloy aging trends will be established using the layer-lap-shear and short-beam-shear data. These tests will be used to establish trends, since they are conducted more frequently and exhibit less variation.

(2) The trends established from (1) will be superimposed on the data obtained from the wafer-lap-shear test. The trend characteristic will be fit to the wafer-lap-shear data in order to establish a regressive line for the lese frequent wafer-shear data. The 3 sigma limits calculated for the line will be used in conjunction with the failure criteria obtained from the Spiralloy Failure Criteria Study to predict the service life of the Wings II through VI case.

(3) Continued evaluation of the failure criteria will be accomplished by analysis of the wafer pressure vessels tested yearly. Testing of the pressure vessels will indicate changes in failure modes and mechanisms.

(4) Wing I case service life will be established by correlation of the Wing I and Wing II case-lap-shear data. Verification of the correlation will be made using the hydroburst data from the aged Wing I cases.



FLEXAGAGE NO.	MEASUREMENT DIRECTION	RADIAL LOCATION FROM ℄ (IN.)
F120	MERIDIAN	9.5
F121	HOOP	10.5
F122	MERIDIAN	12.5
F123	HOOP	10.5
F124	45° TO MER	13.5
F125	45° TO MER	8.5
F126	ALONG FIBER	13.5
F127	ALONG FIBER	8.5
F128	HOOP	10.5
F129	HOOP	10.5

Figure 2-15. Aft Dome Flexagage Location

SECTION VII

PROPELLANT GRAIN SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

This study replaces the previous 3-yr propellant test plan completed in December 1963. (Refer to Appendix A, Section 1.) Results from previous testing indicated that the propellant physical properties changed with time; however, lack of failure criteria prevented prediction of service life with sufficient confidence. This change was attributed to specimen configuration.

This study provides 10-yr data which can be used for service life predictions. Both physical and chemical properties will be studied. The highest stress and strain levels occur in the area of the grain occupied by CYH; therefore, only CYH propellant will be studied. DDP propellant will be available for future testing if required.

An essential requirement for relating trends in propellant physical properties to service life predictions is a stress analysis of the propellant grain. Through a stress analysis, aging data are translated into parameters, such as stress, strain, stored energy, etc, which can be related through a theory of failure to a quantitative measure of the change in the margin of safety. This change can be related, in turn, to service life predictions.

Data obtained from chemical testing will be used to determine the effect of chemical changes in the propellant composition on physical and stability properties, and as a means of predicting propellant stability. Chemical testing will also provide a basis for recommending propellant composition changes should a problem arise in aged propellant. Particular attention is being given to the case-to-liner bond area where the potential reaction between epoxy, rubber, and propellant ingredients exist.

B. DETAILED TEST PLAN

1. Acquisition of Samples

a. Physical Properties Test

The required samples of CYH propellant will be obtained from dissected full-scale grains aged for 2-1/2, 3-1/2, 4-1/2, 5-1/2, and 7-1/2 yr. (Refer to Table 1-2.) The grains are to be cut into three major sections, two sections 10 in. long and one section 18 in. long, as detailed in Appendix B. The two 10-in.-long sections are to be cut into 32 samples. The samples are packaged and placed in storage. Upon scheduled withdrawal from storage, the required amount of specimens will be machined from the samples as shown in Figures 2-16 and 2-17 and tested. The location from which each sample was removed from the grain will be recorded.

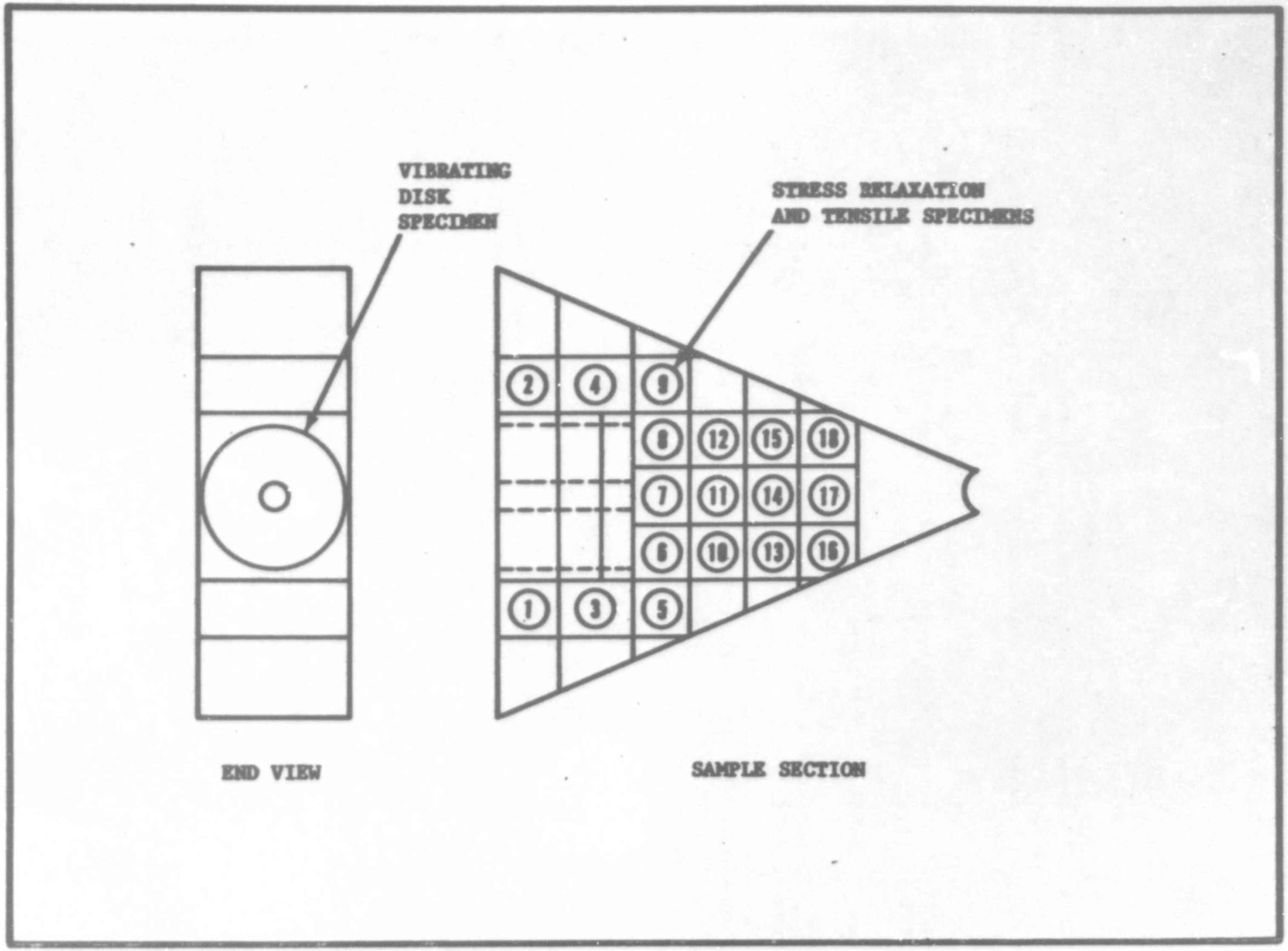


Figure 2-16. Typical Propellant Sample for Series I and II Testing

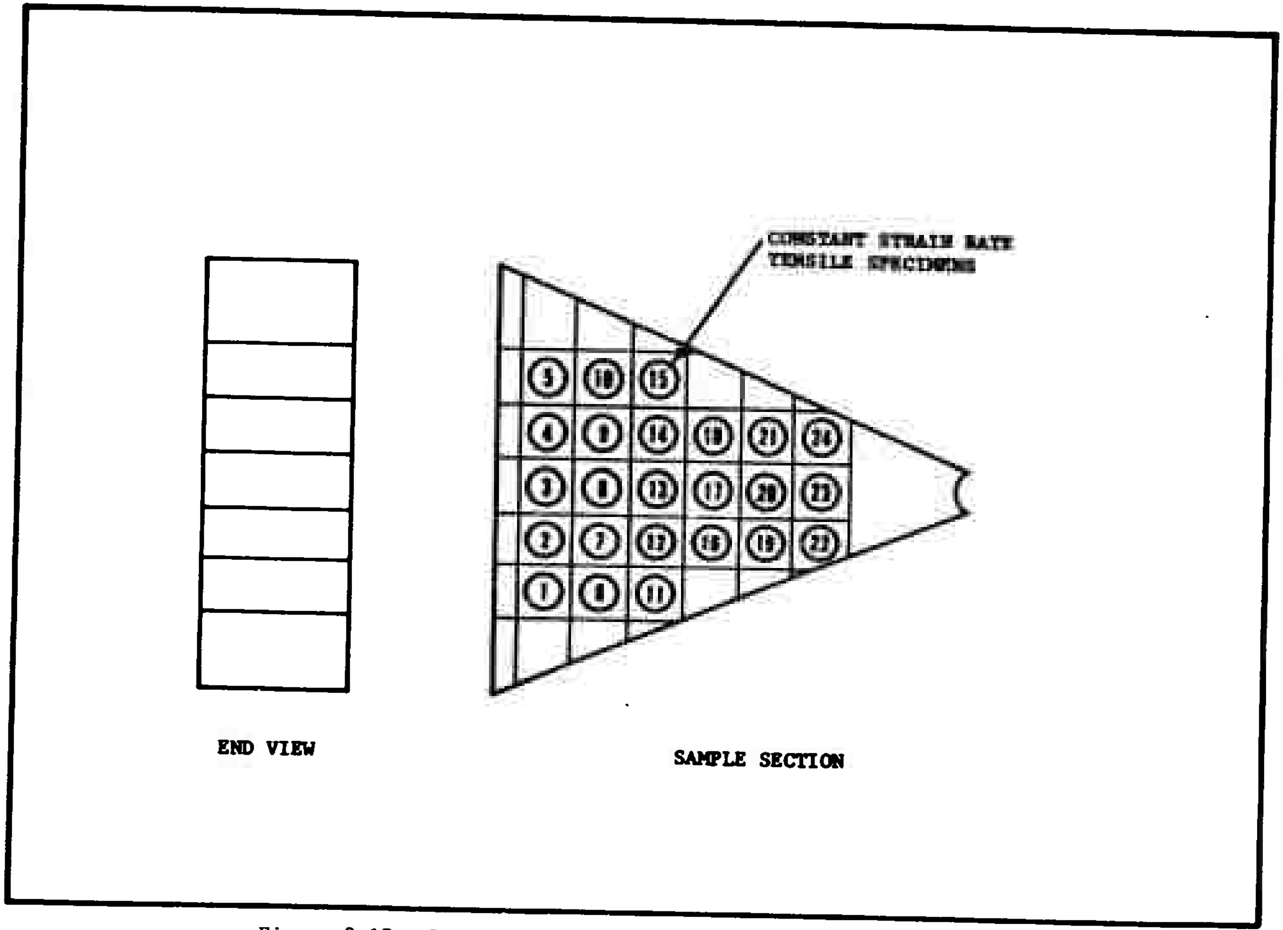


Figure 2-17. Typical Propellant Sample for Series III Testing

b. Chemical Testing

Propellant samples for chemical tests will be obtained from the case-to-propellant bond samples.

The case-to-propellant bond samples are obtained from grains 336 (Wing II) and 216 (Wing I). The 3- by 5-in. sample will provide undisturbed specimens of the case liner, epoxy barrier, and embedment grain and propellant.

The forward and aft dome sections from each dissected FSU grain except for the fwd dome for grain 1M1 will be removed from storage as scheduled in Tables 1-2 and 2-17 and will have the dome removed at the rubber insulator to dome interface as shown in Figures 2-18 and 2-19.

TABLE 2-17

FULL-SCALE UNIT GRAIN CHEMICAL ANALYSIS TEST SCHEDULE

Materials	Grain No.	Zero Time Date*	Test Sequence (mo from zero time)				
			60	66	72	78	90
Forward Dome	336	Dec 62	a				
	216	Dec 61		a			
	131	Jan 61			a		
	67	Jun 60				a	
	70	Jul 60					a
Aft Dome	336	Dec 62	b				
	216	Dec 61		b			
	131	Jan 61			b		
	67	Jun 60				b	
	70	Jul 60					b
	1M1	Dec 62	b				

Legend:

a - Photograph, plot voids, and test 8 each potting compound, shrinkage liner, and propellant chemical specimens.

b - Photograph and test 4 each aft boot and propellant chemical specimens.

*Zero time date is cast date of propellant grain

The forward dome will be photographed, visually inspected, and potting voids will be plotted and compared against previous X-ray reports. Eight 1- by 1- by 1/4-in. samples for chemical analysis will be removed from the propellant and shrinkage liner as described in Figure 2-18.

TABLE 2-18 (Cont)

PHYSICAL PROPERTIES TESTS

Test Series	Test Description	Test Specimens Per Period	Test Conditions: Temp (°F)	Test Conditions: Rate (in./min)	Storage Condition (70° F) Applied Force
III (Cont)	Constant rate tensile	3	70	200	12 mo at
		3	70		1% strain
		3	70		2% strain
					5% strain
		3	70	200	6 mo at
		3	70		2 psi load
		3	70		4 psi load
					8 psi load
		3	70	200	12 mo at
		3	70		2 psi load
		3	70		4 psi load
					8 psi load
	Vibration fatigue				Strain cycled 10^7 cycles at 20 cps
		3	70	200	0.1% strain
		3	70		0.2% strain
		3	70		0.3% strain

The series III tests will be conducted to determine elongation characteristics of the propellant. The loads that will be considered are thermal strains, gravity loading, and transportation and handling. Propellant samples will be subjected to constant strain, constant load, and vibration environments to simulate these loads, and will then be tensile tested at a constant strain rate of 200 in./min. Any changes during the period before tensile testing will be documented. During constant strain and load condition testing, storage of the propellant samples will be at a temperature of 70° F and at ambient humidity.

b. Chemical Testing

Specimens obtained from the case-bond sample section will be used for the chemical testing. The specimens will be machined from the center of the case-bond sample section, and tested as scheduled in Table 2-20. The chemical test schedule corresponds with the FSU case-bond test schedule. The tests to be conducted are described in the following paragraphs.

TABLE 2-19

PROPELLANT PHYSICAL TEST SCHEDULE

Grain No.	Wing No.	Zero Time Date*	Samples Tested From Section No.	Test Sequence (mo)** 30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
336	II	Dec 62	1-1,2-2,3-3,4-4,5-1,6-2 7-3,8-4 1-3,203,3-4,4-1,5-2,6-3	a	b	a													
216	I	Dec 61	1-1,2-2,303,4-4,5-1,6-2 7-3,8-4 1-2,203,304,4-1,5-2,6-3			a	b	a											
131	I	Jan 61	1-1,2-2,3-3,4-4,5-1,6-2 7-3,8-4 1-2,2-3,3-4,4-1,5-2,6-3					a	b	a									
67	I	Jun 60	1-1,2-2,3-3,4-4,5-2,6-2 7-3,8-4 1-2,2-3,3-4,4-1,5-1,6-3 7-4,8-1 1-3,2-4,3-1,4-2,5-3,6-4							a	b	a	b	a					
70	I	Jul 60	1-1,2-2,3-3,4-4,5-1,6-2 7-3,8-4 1-2,2-3,3-4,4-1,5-2,6-3 7-4,8-1 1-3,2-4,3-1,4-2,5-3,6-4 7-1,8-2											a	b	a	b b	a	b
216	I	Dec 61	7-4 8-1 1-3			c d ef	f f	f f	f f										
67	I	Jun 60	7-1 8-2 1-4							c d ef	f f	f f	f f						

*Zero time is cast date of motor

**Test Sequence:

a - Series I tests (Table 2-18)
b - Series II tests (Table 2-18)
c - Start constant strain conditioning (Series III test, Table 3-12)
d - Start constant load conditioning (Series III, test, Table 2-18)
e - Vibration conditioning (Series III test, Table 2-18)
f - Remove three specimens from each condition and conduct tensile test (Series III test, Table 2-18)

SECTION IX

INTERNAL INSULATION SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The Wing I motors utilize a Buna-N rubber (NBR) case liner and asbestos phenolic (RPD-150) in the TT shell and nozzle exit cones. The Wing II through Wing VI motor case liners are made of Buna-S (SBR) material, the TT shells are made of nylon phenolic, and the nozzle exit cones are made of asbestos phenolic.

The extension of this study to 10 yr was accomplished by obtaining specimens from dissected FSU grains. Wing I laboratory specimens will not be prepared because of the extreme negative lead time that would result.

The testing of the laboratory Wing I phenolic and rubber was completed January 1964 after 3 yr of testing. The test plan used is presented in Appendix A, Section II.

B. DETAILED TEST PLAN

1. Sample Preparation

a. Preparation of Laboratory Specimens

Rubber specimens will be cut according to Hercules drawing 1683 BU-2 under conditions allowing minimum exposure to air to prevent undue ozone degradation. The specimens to be coated will then be sanded, degreased with Methyl-Ethyl-Ketone, and allowed to dry for 1 hr preparatory to cutting. The Buna-N tensile specimens will be divided into two groups: one group will be coated with Epon 923, and the other will remain uncoated. Buna-S specimens will be divided into three groups: one group will be coated with Epon 923, one group with C-7, and one group will remain uncoated. The Epon will be mixed, applied and cured as follows:

(1) The Epon will be mixed until well blended according to the following formulas:

Epon 923, Part A	100 gm
Epon 923, Part B	13.2 gm

(2) The Epon will be applied with a brush to an approximate thickness (fairly consistent) of 0.015 in.

(3) Epon 923 will be cured at 120° F for 8 hr.

(4) The rubber specimens coated with C-7 adhesive will be prepared in the same manner as the samples coated with Epon 923. The adhesive will be prepared in accordance with vendor recommendations.

b. Preparation of Samples From Dissected FSU's

Individual internal insulation specimens obtained from dissected motors will be machined from sample sections just prior to testing to prevent specimen damage and to permit aging to continue without direct environmental exposure. (Refer to Appendix B, Figure B-8.)

1) Erosion Specimens

Rubber liner material will be cut, using a band saw, from the area between the TT ports, as shown in Figure 2-23. Sample sections will be cut into test specimens approximately 1/2 by 1 by 4 in. Both surfaces will be machined to remove Spiralloy and to expose only the rubber to the hot gas flow during subscale motor firing. Samples will be removed from storage as scheduled in Table 2-25.

Phenolic sample sections will be cut from the TT phenolics of the aged motors using a special cutting tool and holding jig. The specimens will be machined as shown in Figure 2-24 and will be approximately 1 by 4 in. Withdrawal from storage of the samples will be as scheduled in Table 2-26. Wing I, Buna-N control samples will be machined from hydroburst surveillance cases; and the Wing II, Buna-S control samples will be machined from hydroburst Wing II QA cases. The phenolic control specimens will be obtained from reject or excess TT shells

All control samples will be obtained so that a minimum storage time will be required. The samples will be stored in black polyethylene bags at 60° F. All rubber and phenolic erosion specimens will be machined in accordance with Figure 2-25.

2) Tensile Specimens

The tensile specimens will be machined from the same area as the erosion specimens, as shown in Figure 2-25. The specimens will first be cut from the liner in 1- by 6-in. pieces, machined to a thickness of 1/8 in., and stamped into tensile specimens.

TABLE 2-27

LABORATORY-PREPARED TENSILE SPECIMENS TEST SEQUENCE

Storage Environment (°F)	Applicable Wing No.	Test Samples	Zero Time Date*	Test Sequence (mo from zero time)																								
				0	3	6	9	12	15	18	21	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
100 (with propellant)	I	Uncoated Buna-N	Feb 62		4**	4	4	4	4	4	4	4	4	4														
100 (with propellant)	I	Buna-N 923	Feb 62	12	4	4	4	4	4	4	4	4	4	4														
100 (with propellant)	II - V	Uncoated Buna-S (SBR)	Oct 63	25		3		3		3		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
100 (with propellant)	II - V	Coated SBR/923	Oct 63	25	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
100	II - V	Uncoated SBR	Oct 63			3		3		3		3		3		3		3		3		3		3		3		3
60 (with propellant)	II - V	Uncoated SBR	Oct 63			3		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
60 (with propellant)	II - V	Coated SBR/923	Oct 63			3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3
60	II - V	Uncoated	Oct 63			3		3		3		3		3		3		3		3		3		3		3		3

*Zero time is fabrication date

**Numbers indicate specimens tested

TABLE 2-28

EROSION TEST MOTOR FIRING SCHEDULE

Test No.	Test Date	Material Tested	Age of Material (yr)	FSU Grain No.
S-1	Jul 65	Nylon Buna-S	2-1/2	336
S-2	Aug 65	RPD-150 Buna-N	2-1/2 2-1/2	1-M-1 1-M-1
S-3	Aug 65	RPD-150 Buna-N	4-1/2 4-1/2	131 131
S-4	Feb 66	RPD-150 Buna-N	3 3	1-M-1 1-M-1
S-5	Feb 66	RPD-150 Buna-N	5 5	131 131
S-6	Jul 66	Nylon Buna-S	3-1/2 3-1/2	336 336
S-7	Aug 66	RPD-150 Buna-N	3-1/2 3-1/2	1-M-1 1-M-1
S-8	Aug 66	RPD-150 Buna-N	5-1/2 5-1/2	131 131
S-9	Dec 66	RPD-150	6-1/2	67
S-10	Feb 67	RPD-150 Buna-N	4 4	1-M-1 1-M-1
S-11	Feb 67	RPD-150 Buna-N	6 6	131 131
S-12	Jun 67	RPD-150	7	67
S-13	Jul 67	Nylon Buna-S	4-1/2 4-1/2	336 336
S-14	Aug 67	Buna-N Buna-N	6-1/2 4-1/2	131 1-M-1
S-15	Dec 67	RPD-150	7-1/2	67

TABLE 2-28 (Cont)

EROSION TEST MOTOR FIRING SCHEDULE

Test No.	Test Date	Material Tested	Age of Material (yr)	FSU Grain No.
S-16	Feb 68	Buna-N	7	131
S-17	Jun 68	RPD-150	8	67
S-18	Jul 68	Nylon Buna-S	5-1/2 5-1/2	336 336
S-19	Aug 68	Buna-N	7-1/2	131
S-20	Jan 69	RPD-150	8-1/2	70
S-21	Feb 69	Buna-N	8	131
S-22	Jul 69	Nylon Buna-S	6-1/2 6-1/2	336 336
S-23	Jul 69	RPD-150	9	70
S-24	Jan 70	RPD-150	9-1/2	70
S-25	Jul 70	Nylon Buna-S	7-1/2 7-1/2	336 336
S-26	Jul 70	RPD-150	10	70
S-27	Jul 71	Nylon Buna-S	8-1/2 8-1/2	336 336
S-28	Aug 71	Buna-N	8-1/2	1-M-1
S-29	Feb 72	Buna-N	9	1-M-1
S-30	Jul 72	Nylon Buna-S	9-1/2 9-1/2	336 336
S-31	Feb 73	Buna-N	10	1-M-1

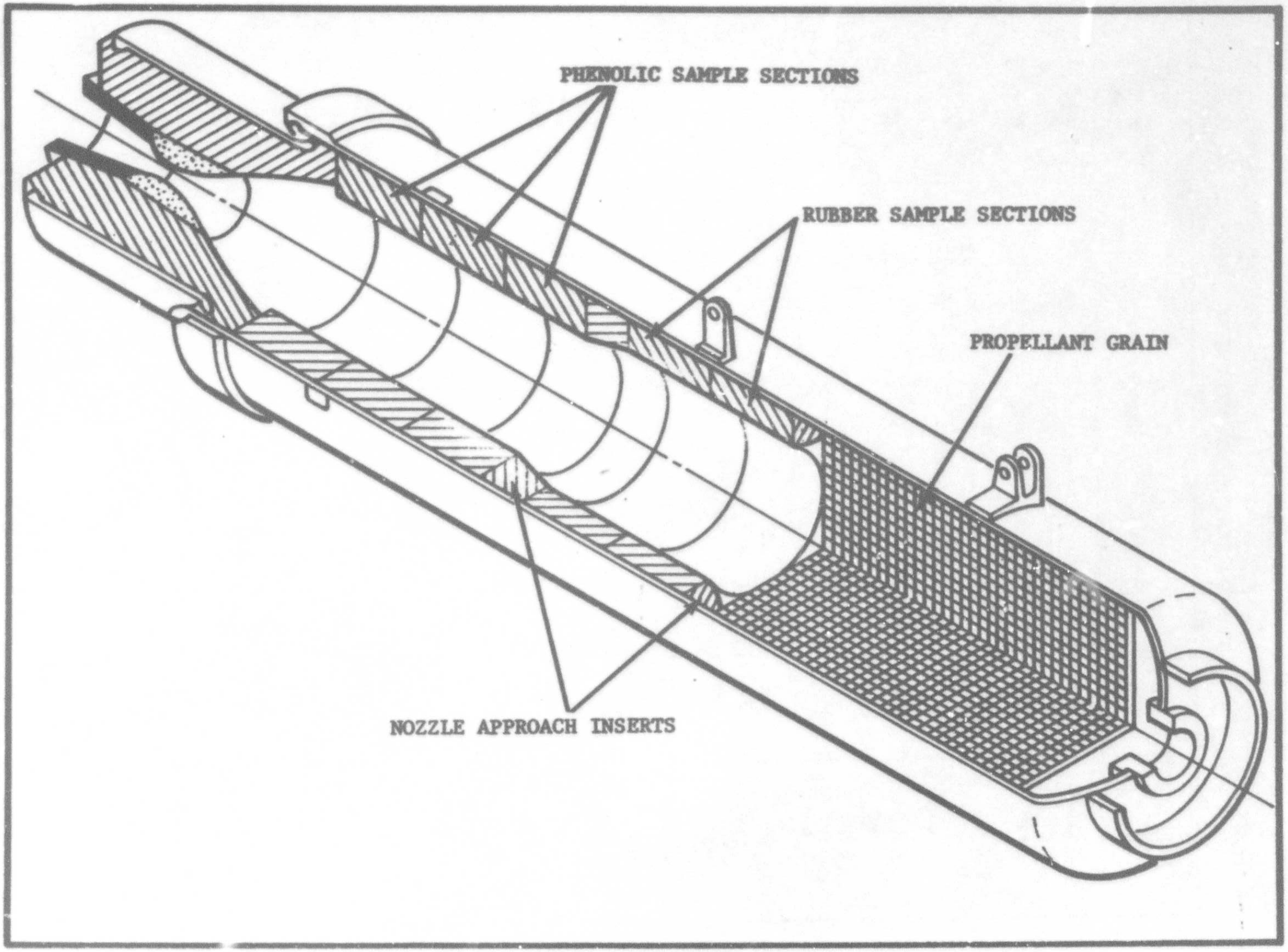


Figure 2-26. Half-Hundred Pound Charge Test Motor

TABLE 2-30

EXTERNAL INSULATION FUNGUS RESISTANCE TEST SCHEDULE

Environment		Test*	Zero Time Date**	No. of Tests	Test Sequence (mo from zero time)														
Temp (°F)	rh (%)				0	3	6	9	12	15	18	21	24	30	36	48	60		
100	35	a	Oct 63	60	4†	4	4	4	4	4	4	4	4	4	4	4	4		
		b		10	***	***	***	***	***	***	***	***	***	***	***	***	***		
80	70	a	Oct 63	60	4	4	4	4	4	4	4	4	4	4	4	4	4		
		b		10	***	***	***	***	***	***	***	***	***	***	***	***	***		
60	35	a	Oct 63	60	4	4	4	4	4	4	4	4	4	4	4	4	4		
		b		10	***	***	***	***	***	***	***	***	***	***	***	***	***		
80	0	a	Oct 63	60	4	4	4	4	4	4	4	4	4	4	4	4	4		
		b		10	***	***	***	***	***	***	***	***	***	***	***	***	***		

*Test:

a = Series I testing

b = Series II testing

**Zero time is fabrication date

***Tests will be conducted until growth occurs

†Numbers indicate specimens tested

Note: 32 specimens will be held for backup

b. Samples for Fungus Resistance Testing

Test samples will be 3-in.-dia circles cut from a sheet of cork which has been backed with Teflon tape to prevent exposure of both sides. The samples to be tested will be coated with XS-1133248 Hypalon coating.

4. Storage

Specimens will be stored at controlled temperature and humidity environments. Samples for physical properties testing will be stored in humidity cabinets. Specimens for fungus resistance testing will be arranged on trays, and placed in humidity cabinets in three environments: (1) 80° F, 35 percent rh; (2) 80° F, 50 percent rh; and (3) 100° F, 35 percent rh.

5. Testing

The adhesive used for bonding the cork insulation to the Spiralloy case is currently being tested as described in Chapter 2, Section XII in this document. The cork insulation will be tested as described in the following subparagraphs.

a. Physical Properties Tests

At each scheduled withdrawal (Table 2-29), each 6- by 7-in. cork sheet will be cut into 10 test samples of 6- by 1/2-in. rectangles. Tests are described in the following subparagraphs.

1) Hardness

Specimens to be used for tensile and flexure testing will have first received the Shore A Hardness (Durometer) Test. This test will be conducted by HPC/B laboratory personnel in accordance with Bacchus Laboratory Procedures Manual, Section III, Method 21. Since this test does not affect tensile or flexure strength, the specimens remain suitable for tensile and flexure testing.

2) Tensile Testing

Tensile testing of cork specimens will be conducted in the Hercules Chemical Propulsion Laboratory in accordance with Bacchus Laboratory Procedures Manual, Section III, Method 8. Testing will provide data on tensile strength and percent elongation.

3) Flexure Testing

Flexure testing of cork specimens will be conducted in the Hercules Chemical Propulsion Laboratory in accordance with Bacchus Laboratory Procedure Manual, Section V, Method 156. Testing will provide data on flexure strength of cork insulation.

b. Fungus Resistance Tests

The testing of Armstrong 2755 cork for fungus growth will be conducted in two series of tests. One series of tests will be the aging of materials in different environments, with the removal of samples and testing for fungus growth in accordance with MIL-E-5272C, Section 4.8. The second test will be periodic inoculation of samples in the ideal growth environment.

Each test sample and control sample will be sterilized prior to inoculation. Sterilization will be accomplished in a fungus cabinet with the use of a bactericidal lamp.

1) Series I

Four samples will be tested from each environment as indicated in Table 2-30. The procedure given in MIL-E-5272C involves sporulation of four strains of fungi in a common incubation vessel and application to the test specimen. The inoculated specimen is then placed in an incubation chamber at $86^{o} \pm 3.6^{o}$ F with 95 ± 5 percent rh for 28 days. After incubation the results will be recorded as negative, meaning no growth, or positive, meaning growth has occurred.

2) Series II

The second part of this particular program will be a modification of the procedure in 1). Ten samples from each environment will be sterilized and inoculated with the common inoculum and placed in storage at 80^{o} F and 100 percent rh. This is considered an ideal growth environment. The date that fungus growth occurs will be recorded. After growth has occurred on a sample, it will be replaced by another sample.

C. DATA EVALUATION

The physical test data does not lend itself to a regression analysis that can be extrapolated to a predetermined failure criteria. However, the data shows no trends of degradation; therefore, a service-life predi-cation of 10 yr has been made.

A service-life predication made in the above manner will continue as long as the overall data gained from testing the material shows no appreciable degradation. If a trend develops, a suitable failure criteria will be established.

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SECTION XI

PRESSURE SEALS SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

To eliminate testing all sizes of O-rings used in the stage III motor, those used in the most critical area were chosen. The O-ring seal in the nozzle pivot section, which is subjected to the most severe conditions, was the seal selected for investigation. The O-rings selected for the study were placed in simulated nozzle pivot sections for storage and testing. Testing of the pivot sections will determine the pivot change in torque wear and sealing characteristics of the assembled O-rings with time.

Various candidates of O-rings and greases for the stage III motor were placed in storage to ensure that the system to be selected for use was under surveillance. When the systems were selected for use in the motor, the remaining system testing was discontinued. The present systems under study are shown in Table 2-31. Pressure seal "ball joint" fixtures will be tested in accordance with Table 2-32.

TABLE 2-31

O-RING AND GREASE COMBINATIONS

System No.	Applicable Wing No.	Parker No.	Spec No.	Material	Grease
9	NA	76-128	AMS 3303	Silicone	DC-55 (silicone)
10	NA	47-641	AMS 7270	Buna-N	DC-55 (silicone)
11	I - VI	47-651	AMS 7274	Buna-N	DC-55 (silicone)
13	NA	77-545	MIL-R-25897	Viton-A	DC-55 (silicone)
14	I - VI	PS-1-30-5	MIL-P-5516A	Buna-N	DC-55 (silicone)

B. DETAILED TEST PLAN

1. Acquisition and Preparation of Samples

The O-rings were obtained from Parker Seal Co., inspected, coated with DC-55 silicone grease, and installed in the test fixtures.

TABLE 2-32

PRESSURE SEAL TEST SCHEDULE (BALL JOINTS)

Fixture No.	System No.	Temp (^{o}F) (amb humidity)	Zero Time Date*	Test Sequence Tested Each Mo to 120 Mo
2	9	100	Jul 60	a
26	9	100	Jul 60	b
10	9	80	Jul 60	a
34	9	80	Jul 60	b
18	9	60	Jul 60	a
42	9	60	Jul 60	b
4	10	100	Jul 60	a
28	10	100	Jul 60	b
12	10	80	Jul 60	a
36	10	80	Jul 60	b
20	10	60	Jul 60	a
44	10	60	Jul 60	b
6	11	100	Jul 60	a
30	11	100	Jul 60	b
14	11	80	Jul 60	a
38	11	80	Jul 60	b
22	11	60	Jul 60	a
46	11	60	Jul 60	b
8	13	100	Jul 60	a
32	13	100	Jul 60	b
16	13	80	Jul 60	a
40	13	80	Jul 60	b
24	13	60	Jul 60	a
48	13	60	Jul 60	b
49	14	100	Mar 65	a
25	14	100	Mar 65	b
3	14	80	Mar 65	a
27	14	80	Mar 65	b
5	14	60	Mar 65	a
29	14	60	Mar 65	b

*Zero time is assembly date of nozzle approach section to exit cone section

a = Breakaway Torque, Cycling, and Pressurization

b = Cycling

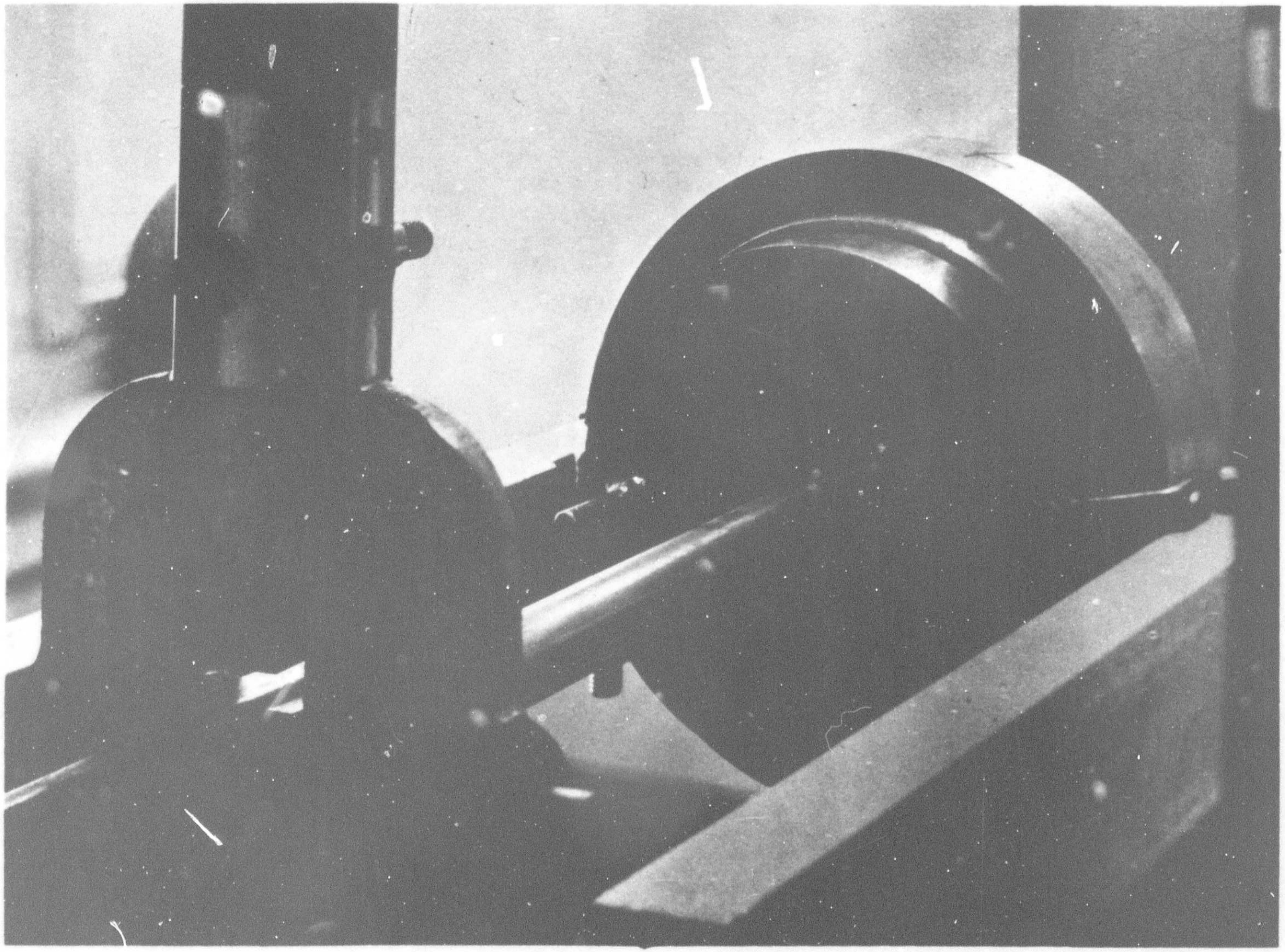

Figure 2-31. Fixture Mounted and Ready for Testing on the Instron

The Instron measures and records the force required to activate the lever arm, and the torque is calculated from this force.

C. DATA EVALUATION

Service life prediction of the O-rings in the nozzle and nozzle port area has been based on an extrapolation of the regression analysis of hardness and elongation data; however, the physical testing of O-rings is complete with the 30-mo testing. The service life value based on this data is 6 yr.

In the future, the service life value will be based on the nozzle ball-joint breakaway torque and pressure seal ability data. The service life prediction has been extended to 10 yr based on this data.

SECTION XII

ADHESIVE AND POTTING COMPOUND SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

This study includes the adhesives and potting compounds used in manufacture of Wings I through VI motors. The adhesives to be studies and the wings to which they apply are as follows:

Adhesive	Applicable Wings
Adhesive Conforming to specification HPC-133-08-3-15 (Shell Epon J-1170-E18), used to bond the external insulation (cork to the motor case (Spiralloy); a blend of Epon 812 and Epon 828	II through VI
Adhesive conforming to specification HPC-133-08-7-8, composition 8 (Shell Epon 934), used to bond the external insulation (cork) to the metallic portion of the nozzles	II through VI
Adhesive confirming to specification HPC-133-08-7-13 (Armstrong A-12-T), used to bond the operational raceway rubber pad to motor case (Spiralloy)	I through VI
Adhesive conforming to specification HPC-133-08-7-8, composition 2 (Epon 923), used as powder embedment bonding agent	I through IV
Adhesive conforming to specification HPC-133-02-3-10, composition 1 (C-7), 60/40 resin to curing agent ratio, used as a rubber-to-rubber bond (boot to insulator)	II through VI

(Paragraph deleted)

The potting compounds to be studied and the wings to which they apply are as follows:

Potting Compound	Applicable Wings
Compound conforming to specification HPC-133-08-3-21A (Shell Epon 937.2), used in potting the external insulation (cork) in the motor's aft dome area	II through VI
Compound conforming to specification HPC-133-08-1-20 (Dow Corning DCQ-9-0024), used for potting around the nozzle boot (rubber) in the ball joint area	I through VI
Compound conforming to specification HPC-133-02-3-113, composition 2 (RTV-88/RTV-9950), used for potting in the aft dome	I through VI
Compound conforming to specification HPC-133-02-3-113, composition 4 (RTV-77/Thermolite/2), used for potting in the aft dome	I through VI
Compound conforming to specification HPC-133-02-3-9 (Sealing Compound Urethane), aft dome potting	I through VI
Compound conforming to military specification MIL-P-8116 (CS), potting around nozzle-to-propellant interface	I through IV
BPC No. 1, potting around nozzle-to-propellant interface	IV

B. DETAILED TEST PLAN

The types of specimens to be used and the quantity of each are as listed in Table 2-33. Specimen configuration was chosen to simulate suspected modes of failure for each adhesive being studied. Testing will be conducted as indicated in Tables 2-34 and 2-35.

1. Preparation of Specimens

a. Lap Shear Samples

Individual coupons, 1- by 4-in. size, will be prepared for each adhesive composition, as indicated in Table 2-33. Two coupons will

TABLE 2-33

ADHESIVE AND POTTING COMPOUND
MATERIALS AND TEST DESCRIPTION

Material	Type of Test	Type of Sample*	Orig Qty
J 1170 E-18 (828-812 blend)	Tensile Lap shear	JANAF Al/cork/Spiralloy	96 96
A-12-T	Tensile Lap shear	JANAF Al/NBR/Al	96 96
Epon 934	Tensile Lap shear	JANAF Al/cork/Spiralloy	96 96
Epon 937.2	Tensile	JANAF	96
DC-Q-9-0024	Lap shear	Al/silicone rubber/Al	96
Thixon CB-2	Lap shear	Al/Al	96
RTV-77	Tensile	JANAF	96
RTV-88	Tensile	JANAF	96
Epon 923	Tensile Lap shear	JANAF Al/Al	96 96
C-7 60/40	Tensile Lap shear	JANAF Al/Al	96 96
C-7 60/40	Lap shear Lap shear Peel Peel	Al/NBR/Al - BPC-1/CYH Al/SBR/Al - BPC-1/CYH NBR/NBR - BPC-1/CYH SBR/SBR - BPC-1/CYH	120 120 120 120
C-7 80/20	Lap shear Lap shear Peel Peel	Al/NBR/Al - BPC-1/CYH Al/SBR/Al - BPC-1/CYH NBR/NBR - BPC-1/CYH SBR/SBR - BPC-1/CYH	120 120 120 120

*Type of Sample: JANAF (See Figure 2-32), Lap Shear (See Figure 2-32), Peel (See Figure 2-34), Al = Aluminum, NBR = Buna-N rubber, SBR = Buna-S rubber, BPC = Bacchus potting compound, CYH = Propellant

TABLE 2-33 (Cont)

ADHESIVE AND POTTING COMPOUND
MATERIALS AND TEST DESCRIPTION

Material	Type of Test	Type of Sample*	Orig Qty
Urethane	Chem analysis and compatibility	Compatibility	10
CS	Chem analysis and compatibility	Compatibility and B_1 fix configuration	8
BPC	Chem analysisx compatibility and viscosity	Compatibility and B_1 fix configuration	8

*Type of Sample: Compatibility (See Figures 2-35 and 2-36), B_1 (See Figure 2-33), Al = Aluminum, NBR = Buna-N rubber, SBR = Buna-S rubber, BPC = Bacchus Potting Compound, CYH = Propellant

overlap and provide a bonded surface area of 1 sq in. (See Figure 2-32.) When cork or rubber is to be tested jointly with Spiralloy or aluminum coupons, the cork or rubber will be cut to a 1-sq-in. section and placed between the overlap area to be bonded. The procedure is as follows:

(1) Thoroughly clean the faying surfaces of the test specimens with methyl-ethyl-ketone and clean cheesecloth.

(2) Apply an even coat of the applicable adhesive, mixed in accordance with manufacturer's recommendations, to each faying surface area to be bonded.

(3) Assemble specimens and apply sufficient pressure to ensure complete contact.

(4) Cure specimens in accordance with manufacturer's recommendations.

(5) Remove specimens from holding fixtures.

b. Tensile "Dog Bone" Samples

Tensile "dog bone" samples will be cast or machined for the adhesive, as indicated in Table 2-33, to produce tensile specimens conforming to Hercules drawing No. 1638-BU-2B.

TABLE 2-34

ADHESIVE AND POTTING COMPOUND TEST SCHEDULE

Materials	Test	Zero Time Date*	Store Temp (°F)	Test Sequence (mo from zero time) 0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
J1170-E18	Tensile	Jun 64	100	4**	4	4	4	4	4	4	4	4	4	4					
	Tensile	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
	Lap shear	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
A12T	Tensile	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
	Lap shear	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
Epon 934	Tensile	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
	Lap shear	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
DCQ-9-0024	Lap shear	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
Epon 937.2	Tensile	Jun 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	Jun 64	80	4		4		4		4		4		4	4	4	4	4	4
RTV 77	Tensile	May 65	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	May 65	80	4		4		4		4		4		4	4	4	4	4	4
RTV 88	Tensile	May 65	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	May 65	80	4		4		4		4		4		4	4	4	4	4	4
Epon 923	Tensile	Jan 65	100	4	4	4	4	4	4	4	4	4	4	4					
	Tensile	Jan 65	80	4		4		4		4		4		4	4	4	4	4	4
	Lap shear	Aug 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Aug 64	80	4		4		4		4		4		4	4	4	4	4	4

*Zero time is fabrication date

**Number of specimens tested

TABLE 2-34 (Cont)

ADHESIVE AND POTTING COMPOUND TEST SCHEDULE

Materials	Test	Zero Time Date*	Store Temp (°F)	Test Sequence (mo from zero time)															
				0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
C-7	Tensile	Aug 64	100	4**	4	4	4	4	4	4	4	4	4	4					
	Tensile	Aug 64	80	4		4		4		4		4		4	4	4	4	4	4
	Lap shear	Aug 64	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Aug 64	80	4		4		4		4		4		4	4	4	4	4	4
Thixon CB2	Lap shear	Nov 65	100	4	4	4	4	4	4	4	4	4	4	4					
	Lap shear	Nov 65	80	4		4		4		4		4		4	4	4	4	4	4
C-7/SBR																			
(80/20)	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(80/20)	Lap shear	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(80/20)	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(80/20)	Peel	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(60/40)	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(60/40)	Lap shear	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(60/40)	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(60/40)	Peel	Nov 65	60			6		6		6		6		6	6	6	6	6	6
C-7/NBR																			
(80/20)	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(80/20)	Lap shear	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(80/20)	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(80/20)	Peel	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(60/40)	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(60/40)	Lap shear	Nov 65	60			6		6		6		6		6	6	6	6	6	6
(60/40)	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
(60/40)	Peel	Nov 65	60			6		6		6		6		6	6	6	6	6	6

*Zero time is fabrication date

**Number of specimens tested

Last page of Table 2-34 is incorporated in Table 3-12 in Volume II.

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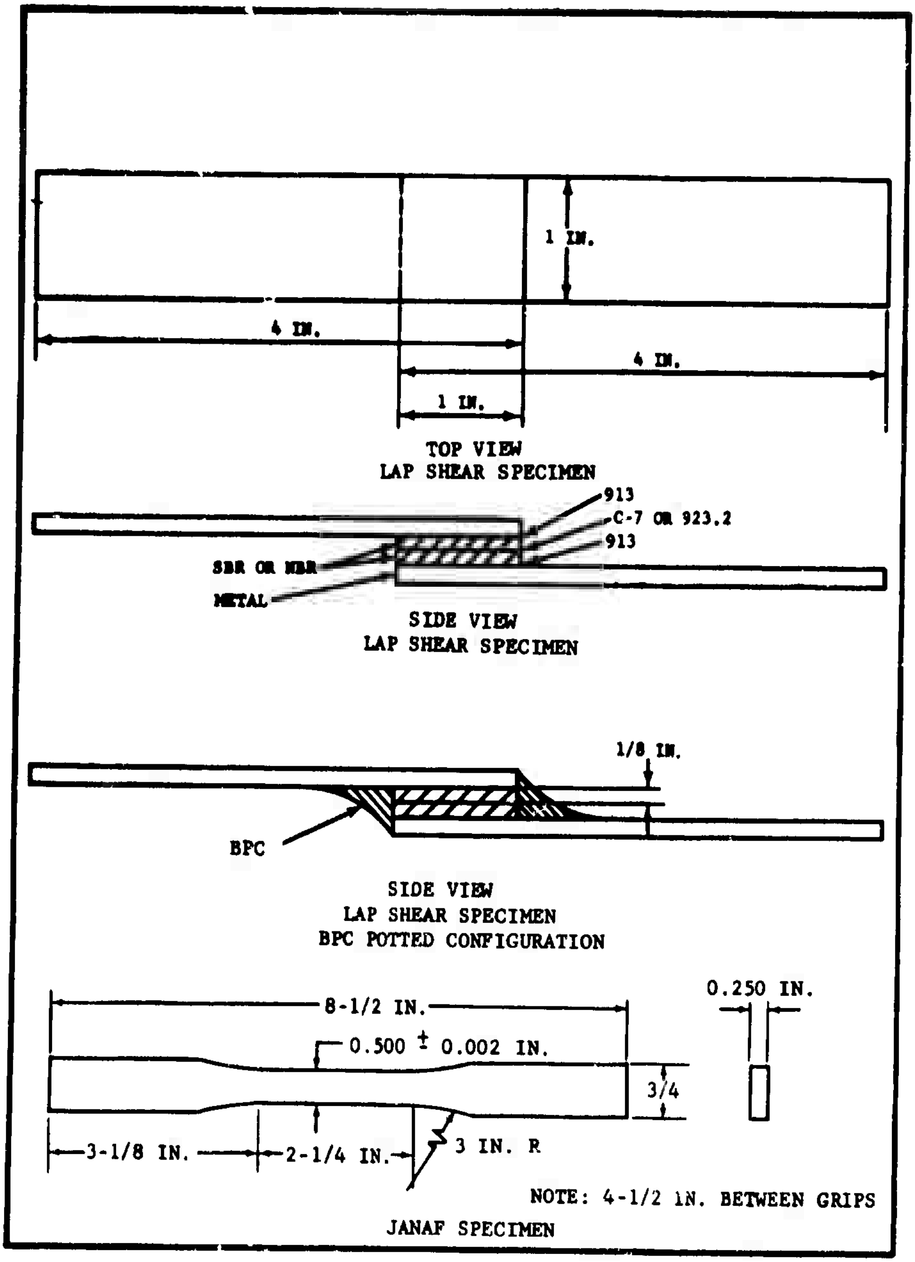

Figure 2-32. Lap Shear and JANAF Specimens

TABLE 2-35

POTTING COMPOUND/PROPELLANT COMPATIBILITY TEST SCHEDULE

Materials*	Test	Zero Time Date**	Store Temp (^{o}F)	Test Sequence (mo from zero time)***										
				0	6	12	18	24	30	36	42	48	54	60
B-1 Fix Specimen (BPC-1)	Visual	May 65	100	a	a	a	a	a	a	a	a	a	a	a
	Control	May 65	100	a	b	b	b	b	b	b	b	b	b	b
	Visual	May 65	60	a	a	a	a	a	a	a	a	a	a	a
	Control	May 65	60	a	b	b	b	b	b	b	b	b	b	b
CYH/BPC-1	Compat	Oct 64	100	a	c	c	c	c	c	c	c	c	c	c
	Compat	Oct 64	60	a	c	c	c	c	c	c	c	c	c	c
	Compat	Oct 64	100	a	c	c	c	c	c	c	c	c	c	c
	Compat	Oct 64	60	a	c	c	c	c	c	c	c	c	c	c
	Compat	Apr 65	100	a	c	c	c	c	c	c	c	c	c	c
	Compat	Apr 65	60	a	c	c	c	c	c	c	c	c	c	c

*Material = B_1 Fix (See Figure 2-33) - CYH (See Figures 2-35 and 2-36)
**Zero time is fabrication date
***Test Sequence:
a = Inspect and photograph
b = Remove from storage, inspect, vibrate, and photograph
c = Visual inspection and chemical analysis

c. <u>Cast Samples</u>

Cast samples are prepared according to the following procedure:

(1) Specimens individually prepared for each adhesive and potting compound.

(2) The molds are thoroughly cleaned with methylethylketone and cheesecloth and a thin coat of mold release (slip spray) is applied.

(3) The compositions are mixed in accordance with manufacturer's recommendations, and poured into the molds.

(4) Specimens are cured in accordance with manufacturer's recommendations.

(5) Specimens are removed from molds.

d. Machined Samples

In preparing samples for machining, sheets of the adhesive or potting compounds will be prepared and cured in accordance with manufacturer's recommendations. These sheets will then be machined to specimens conforming to Hercules drawing 1638-BU-2B.

e. B-1 Fix Configuration Specimen

Base plates of 4-1/2 by 4-1/2 by 1/4-in. aluminum will be drilled with eight 1/4-in.-dia holes at 45° angles on a 1-13/16 in. radius. (See Figure 2-33.) SBR rubber will be cut into six 3-in.-dia sections and two 2-in.-dia sections using 1/8-in. rubber stock. CYH propellant will be machined into six blocks 3 in. in dia and 3 in. high, and two blocks 2 in. in dia and 3 in. high. The six 3-in.-dia blocks will have a 3/4 x 3/4-in. machined groove. Procedure is as follows:

(1) Aluminum base plates are sand-blasted and degreased.

(2) Concentric lines are scribed at center, 1/8 in. apart, starting at 3 in. dia and stopping at 4 in. dia.

(3) Rubber is sanded and degreased.

(4) Aluminum plates are degreased.

(5) 913 adhesive is mixed.

(6) Rubber is bonded to base plates with 913 adhesive and allowed to cure at ambient temperature.

(7) Rubber is degreased.

(8) Epon 923.2 adhesive is mixed.

(9) Machined CYH sample is bonded with rubber using Epon 923.2 adhesive and allowed to cure as recommended by adhesive manufacturer.

(10) Groove in B-1 Fix samples is potted with BPC, to ensure a clean and smooth surface.

(11) CYH/BPC sample is potted around base.

(12) CYH/CS sample is potted around base.

(13) Propellant is marked with storage temperature, date, and type of sample.

(14) Propellant is placed in proper storage environments.

SECTION XIV

CASE-BOND FAILURE CRITERIA STUDY

A. INTRODUCTION

The objectives of this program are to: (1) Determine from stress analyses the modes of failure for the case-bond systems in the Minuteman Wing I, Wings II through V, and Wing VI stage III motors; (2) fabricate and evaluate specimens which will provide measurable parameters for each of the modes of failure determined; and (3) establish failure criteria, i.e., limits for these parameters, which can be related to the performance of the motor.

Although many case-bond test methods have been developed throughout the solid propellant industry, few of them have been related mathematically to stress analysis results.

It is assumed that the failure theories which permit the prediction of failure within the propellant grain will predict the failure within the case-bond system providing the material properties are known. To evaluate this assumption, it is necessary to determine the material properties of the case-bond system and to develop samples in which controlled failures can be induced and then compared with predicted failures. This study, therefore, is concerned with the development of case-bond test specimens and test methods by which the material properties of the case-bond system can be determined and propellant failure theories can be evaluated in the case-bond area.

B. APPROACH

Test methods which impose multiaxial stress conditions of known magnitude on the case-bond system will be reviewed and evaluated. Some of the tests being considered are the "poker chip", "scarf joint", torsion, torsion-tension, torsion-tension-pressure, and tension test.

Test specimens for many of these tests present fabrication problems in the area of the case bond. The large differences in tensile strength; elongation; and modulus of the Buna-S rubber (Styrene-Butadiene Rubber), Epon 923 epoxy embedment resin (a flexible poly-epoxide resin), and propellant tend to weaken or destroy the case bond during the machining of test specimens. As the cutting tool used in machining enters the Buna-S rubber, the rubber elongates 200 to 300 percent, whereas the embedment resin only elongates 20 to 30 percent. Consequently, fracture lines propagate through the embedment resin to relieve the stresses. It is a further aim of this study to develop techniques by which test specimens can be fabricated.

Fabrication techniques will be evaluated by loading the various case-bond specimens to failure under uniaxial tension and/or multiaxial

tension-torsion. Data obtained from these tests will be analysed by failure theories, and the best test method and test specimens selected for further evaluation.

These investigations will be conducted in two phases of study: (1) Feasibility studies and (2) failure analyses studies. The first phase will be a literature survey of case-bond test specimens and the evaluation of fabrication techniques and specimen configurations by uniaxial and multiaxial tests. The second phase will be a statistical analysis of test failures to establish a mode of failure in the test specimens. These analyses will include both uniaxial and multiaxial failures.

C. DETAILED TEST PLAN

1. Test Program, Phase I

The literature survey will be used to determine test specimens and test methods by which case-bond systems may be characterized. Mathematical stress analyses will be performed to assist in the selection of the most suitable test specimens and test methods. Techniques of fabricating the test specimens will be determined.

Limited testing will be conducted to evaluate the fabrication techniques and to establish the relationships between the selected test specimens and those used to accumulate previous case-bond physical property data. These tests will consist of uniaxial tension, simple torsion, and double-lap shear which have been used previously.

a. Preparation of Case-Bond System

Two case-bond beakers will be powder loaded, cast, and cured in accordance with standard operating procedures for CYH propellant. Each beaker will contain a case-bond system of Buna-S rubber, a barrier coat of Epon 923 resin, Epon 923 embedment resin, and CYH base grain embedment. The case-bond systems will be preapred in the Materials Development Laboratory. Specific instructions for the preparation of the case-bond systems are as follows:

(1) Cut four strips of Buna-S Rubber 8 by 30 by 1/8 in. (width, length, thickness).

(2) Clean one surface of each strip of Buna-S rubber with tri-clean and allow to dry.

(3) Apply a 15-mil-thick barrier coat of Epon 923 epoxy on the cleaned Buna-S rubber.

(4) Cure Epon 923 epoxy for 18 hr at 120° F.

(5) Apply a 15-mil-thick embedment layer of Epon 923 over the barrier coat.

(6) Record refactory index (RI) number every 30 min.

(7) Embed when Δ RI equals 50 to 70.

(8) Weigh embedment powder and record.

(9) Sprinkle CYH embedment grain over the epoxy, making sure that maximum coverage is obtained.

(10) Invert embedded rubber to remove excess powder and weigh excess powder. Subtract excess powder weight from total weight of embedment powder.

(11) Cure for 16 hr at 120° F.

(12) Clean uncoated side of Buna-S rubber with tri-clean and allow to dry.

(13) Apply a 15- to 20-mil-thick coat of Epon 913.1 to back of one rubber panel.

(14) Bond a second rubber panel to form a sandwich. (Embedded surfaces must be to the outside.)

(15) Cure for 16 hr at 77° F under 1 psi pres e.

(16) Mount case-bond system in a cellulose acetate frame.

(17) Install mounted case-bond system in a case-bond test beaker.

(18) Powder load with CYH casting powder, solvent cast, and cure per standard operating procedures.

(19) Secure a polyethylene panel 8 by 30 by 1/2 in.

(20) Apply a 15- to 20-mil-thick layer of Multron potting compound to both surfaces of the poly-ethylene panel.

(21) Affix one Buna-S rubber embedded case-bond panel to each surface. (Embedded surface must be to the outside.)

(22) Cure for 16 hr at 77° F under 1 psi pressure.

(23) Install polyethylene panel with case-bond system in a case-bond test beaker.

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(6) Record refactory index (RI) number every 30 min.

(7) Embed when Δ RI equals 50 to 70.

(8) Weigh embedment powder and record.

(9) Sprinkle CYH embedment grain over the epoxy, making sure that maximum coverage is obtained.

(10) Invert embedded rubber to remove excess powder and weigh excess powder. Subtract excess powder weight from total weight of embedment powder.

(11) Cure for 16 hr at 120° F.

(12) Clean uncoated side of Buna-S rubber with tri-clean and allow to dry.

(13) Apply a 15- to 20-mil-thick coat of Epon 913.1 to back of one rubber panel.

(14) Bond a second rubber panel to form a sandwich. (Embedded surfaces must be to the outside.)

(15) Cure for 16 hr at 77° F under 1 psi pressure.

(16) Mount case-bond system in a cellulose acetate frame.

(17) Install mounted case-bond system in a case-bond test beaker.

(18) Powder load with CYH casting powder, solvent cast, and cure per standard operating procedures.

(19) Secure a polyethylene panel 8 by 30 by 1/2 in.

(20) Apply a 15- to 20-mil-thick layer of Multron potting compound to both surfaces of the polyethylene panel.

(21) Affix one Buna-S rubber embedded case-bond panel to each surface. (Embedded surface must be to the outside.)

(22) Cure for 16 hr at 77° F under 1 psi pressure.

(23) Install polyethylene panel with case-bond system in a case-bond test beaker.

(24) Powder load with CYH casting powder solvent, cast, and cure per standard operating procedures.

b. <u>Machining of Test Specimens</u>

After the propellant has been cured, grain 1 will be sawed into eight sections as shown in Figure 2-53. Sections A through F will be machined into test specimens as shown in Figures 2-54 and 2-54A. Grain 2 will be sectioned as shown in Figure 2-54B and then machined into test specimens as shown in Figure 2-54C.

All machining will be performed in the presence of technical personnel so that fabrication techniques can be evaluated. Detailed instructions and drawings of the machining operations will be supplied by the technical man responsible for the project. General machining drawings and instructions are as follows:

(1) Grain 1

(a) Remove a 1.75-in. slice from the base of the grain (perpendicular to case-bond system) (cut 1).

(b) Remove a 0.75-in. slice along the length of the grain (parallel with case-bond system) (cut 2).

(c) Remove a 1.75-in. slice along the length of the grain (parallel with case-bond system) (cut 3).

(d) Label this 1.75-in. slice as Section F.

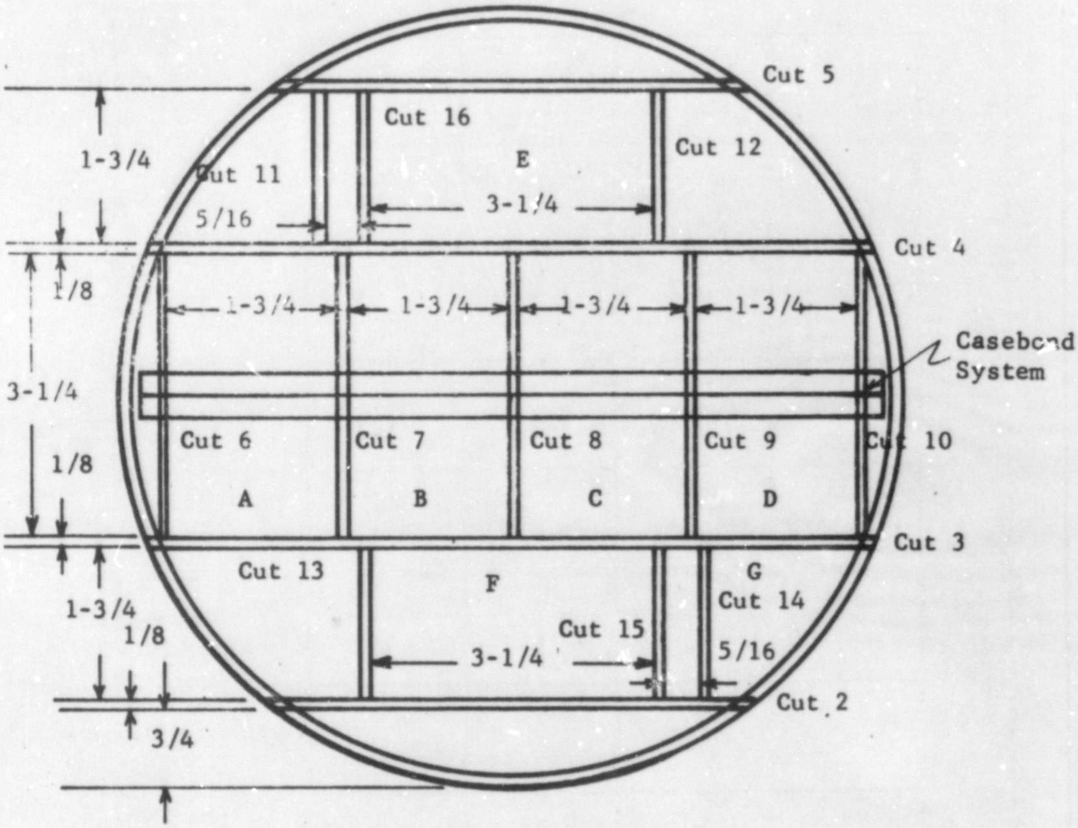
(e) Remove a 3.25-in. slice along the length of the grain. This slice will contain the case-bond system in the center of the section (cut 4).

(f) Remove a 1.75-in. slice along the length of the grain (cut 5).

(g) Label this slice as Section E.

(h) Using the 3.25-in. slice removed in Step 5, remove a 0.35-in. slice along the length of the grain (perpendicular to case-bond system) (cut 6).

(i) Remove successive 1.75-in. slices along the length of the grain (cuts 7, 8, 9, and 10).



SECTION	DIMENSIONS	
A	1-3/4 x 3-1/4 x 30	
B	1-3/4 x 3-1/4 x 30	CASEBOND IN
C	1-3/4 x 3-1/4 x 30	CENTER OF 3-1/4
D	1-3/4 x 3-1/4 x 30	MEASUREMENT
E	1-3/4 x 3-1/4 x 30	PROPELLANT
F	1-3/4 x 3-1/4 x 30	(TENSILE & TORSION)
G	5/16 x 1-3/4 x 30	PROPELLANT
H	5/16 x 1-3/4 x 30	(LAP SHEAR)

NOTE: ALL DIMENSIONS MEASURED IN IN.

Figure 2-53. End View of Detailed Machining Plan (Grain No. 1)

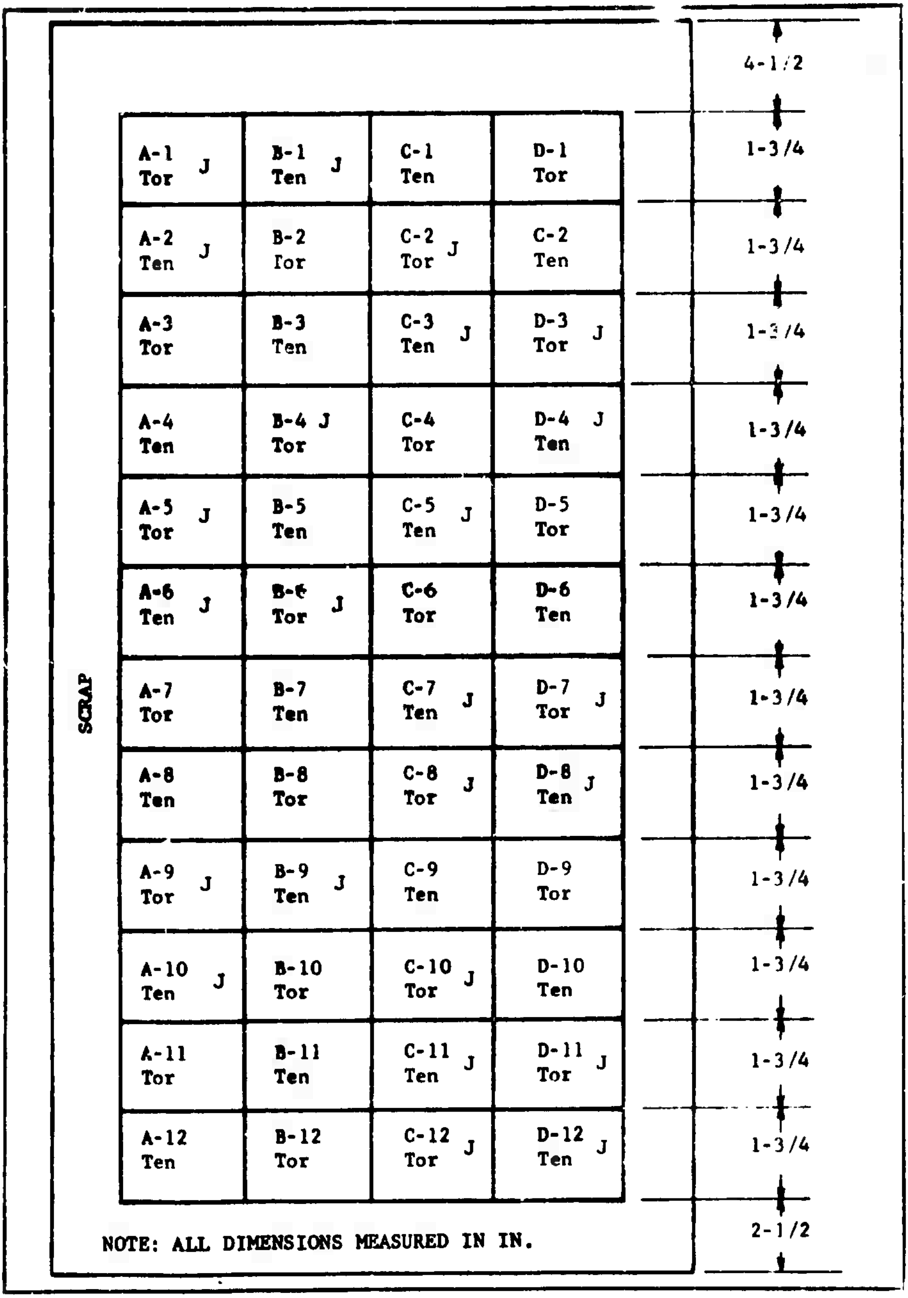


Figure 2-54. Side View of Detailed Machining Plan (Grain No. 1)

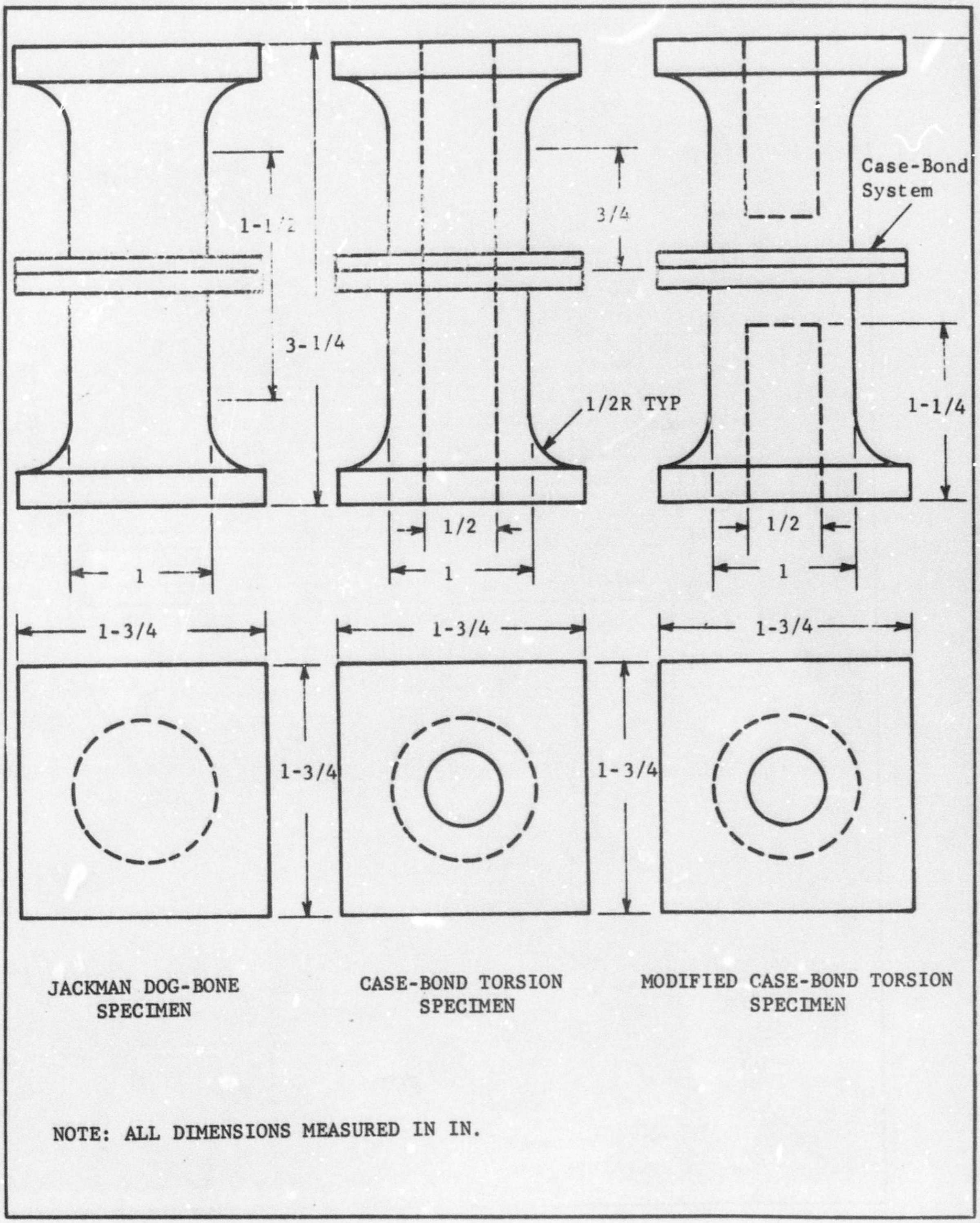
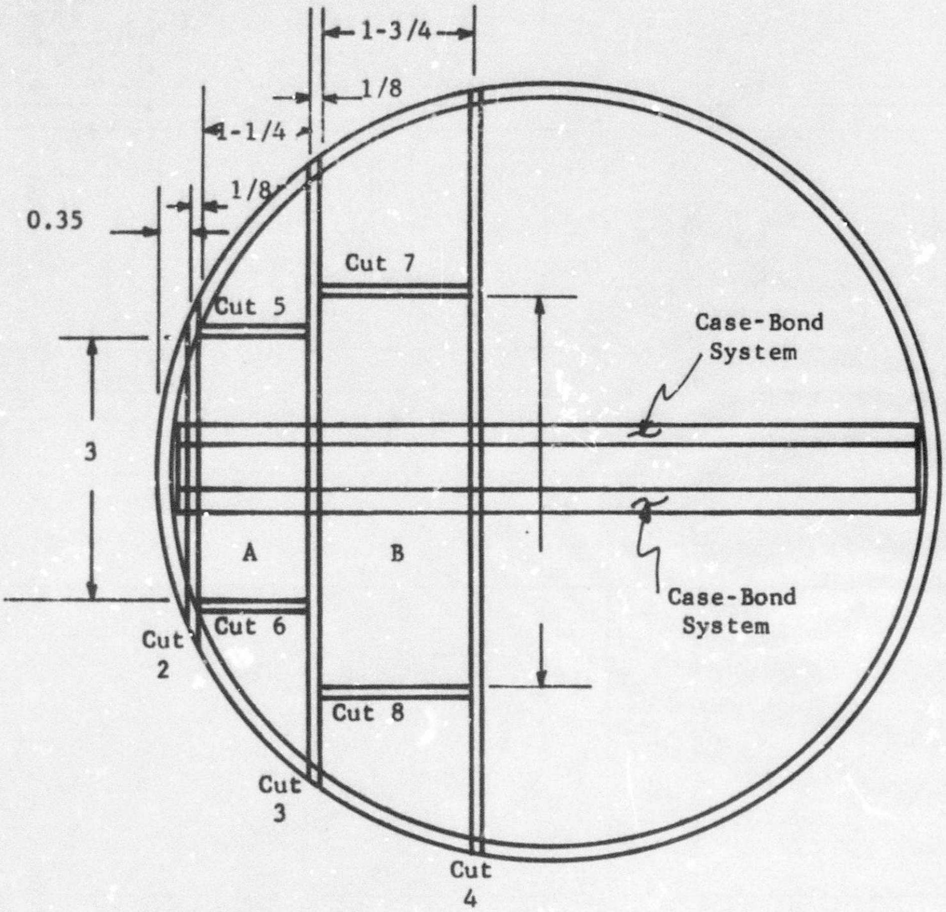


Figure 2-54A. Detailed Specimen Machining Plan (Grain No. 1)



Section A   3 x 1.25 x 30   (Torsion, Lap Shear, Scarf Joint)
Section B   4 x 1.75 x 30   (1/2 Jackman Dogbone and 1/2 Case-Bond Torsion)

NOTE: ALL DIMENSIONS MEASURED IN IN.

Figure 2-54B. End View of Detailed Machining Plan (Grain No. 2)

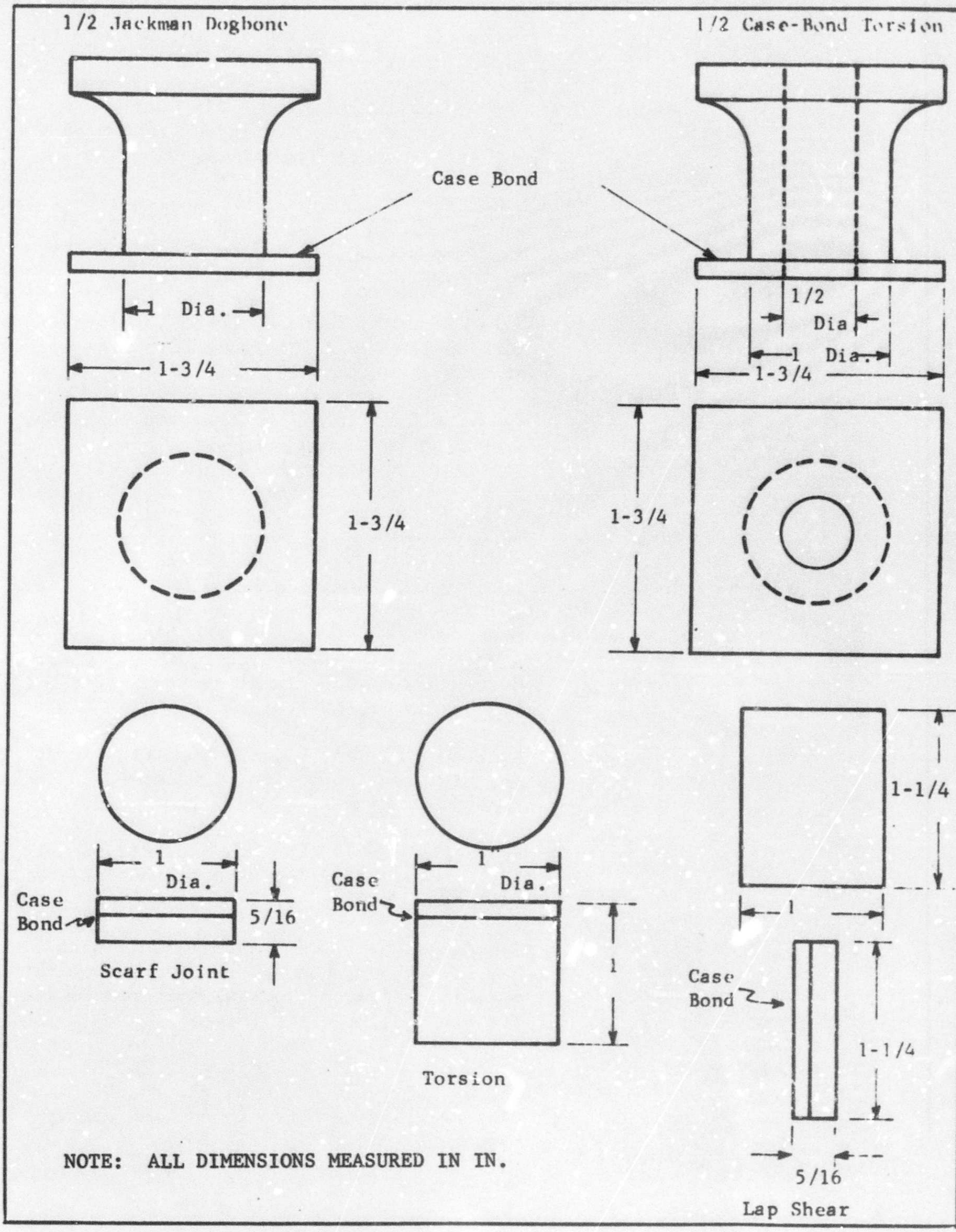


Figure 2-54C. Detailed Specimen Machining Plan (Grain No. 2)

(j) Label each slice as it is removed from the grain with consecutive capital letters (A, B, C, D, etc).

(k) Cut each slice to form 1.75- by 1.75- by 3.25-in. specimens having the case bond in the center of each specimen.

(l) Label each specimen with the slab letter and a numeral, i.e., A1, A2, A3, ... A12. Numerals are to begin from the top and run to the bottom of the grain.

(m) Using Sections E and F, remove a 3.625-in. section of propellant from the center section of each slab (cuts 11, 12, 13, 14).

(n) Remove a 0.25-in. slice from the length of each slab to form a 0.25- by 1.75- by 30-in. section. Identify these sections as G and H and wrap in aluminum foil (cuts 15, 16).

(o) Take the remaining propellant from Sections E and F and cut each slice into 1.75- by 1.75- by 3.25-in. specimens.

(p) Label each specimen with the slab letter and a numeral (i.e., E1, E2, E3 ... E12). Numerals are to begin at the top and run to the bottom of the grain.

(q) Specimens E1, E3, E5, E7, E11, F2, F4, F6, F8, F10, and F12 are to be machined to Jackman dogbone specimens. (See Figure 2-53.)

(r) Specimens E2, E4, E6, E8, E10, E12, F1, F3, F5, F7, F9, and F11 are to be machined to case-bond torsion specimens. (See Figure 2-54.)

(s) Specimens C3, D3, C4, A5, A6, C6, D6, A7, A8, B9, C9, and C10 are to be machined to modified case-bond torsion specimens. (See Figure 2-54.)

(t) Specimens A1, A2, A9, A10, B1, B4, B6, C2, C5, C7, C[illegible], C11, C12, D4, D7, D8, D11, and D12 are to be machined to Jackman dogbone specimens. (See Figure 2-53.)

(u) Specimens A3, A4, A11, A12, B2, B3, B5, B7, B8, B10, B11, B12, C1, D1, D2, D5, D9, and D10 are to be machined to case-bond torsion specimens. (See Figure 2-54.)

(v) Sections G and H will be cut up into 1- by 1-1/2- by 5/16-in. lap-shear specimens.

(2) Grain 2

(a) Remove a 1.75-in. section from the bottom of the grain (perpendicular to case-bond system) (cut 1).

(b) Remove a 0.35-in. slice along the length of the grain (perpendicular to case-bond system) (cut 2).

(c) Remove a 1.25-in. slice along the length of the grain (perpendicular to case-bond system) (cut 3). (Identify as Section A.)

(d) Remove a 1.75-in. slice along the length of the grain (perpendicular to case-bond system) (cut 4). (Identify as Section B.)

(e) Wrap the remainder of the grain in aluminum foil for storage.

(f) Using Section A, remove the excess propellant from each side so that a section with the case-bond system in the center 3- by 1.25- by 30-in. is formed.

(g) Machine this section into 3- by 1.25- by 1.25-in. specimens.

(h) Identify each specimen with A1, A2, A3 ... Numerals are to begin from top and run to the bottom of the grain.

(i) Specimens for lap shear tests, torsion tests, and scarf joint tests will be specified by the technical personnel observing the machining.

(j) Specimens for propellant characterization will be obtained from the excess propellant as Step 9 and will be specified at a later date.

(k) Using Section B remove the excess propellant to form a 1.75- by 4- by 30-in. section with the case-bond system in the center of the 4-in. measurement.

(l) Machine 1.75- by 1.75- by 4-in. specimens from this specimen.

(m) Identify each specimen with a letter and a numeral, i.e., B1, B2, B3, ... B12.

(n) Machine modified Jackman dogbones from each specimen. (See Figure 2-54C.)

(o) Specimens will be selected at a later date to prepare case-bond torsion specimens. Each specimen, B1, B2, B3, etc, will make two test samples.

(p) Machining instructions for the remainder of grain No. 2 will be issued after preliminary testing has indicated a suitable test specimen.

c. <u>Evaluation of Case-Bond Specimens</u>

Physical property characterization studies will be used to supplement available data. The purpose of these studies is to accumulate information which is not available and is required for the stress analyses. Typical characterization studies which may be required would be allowable tensile stress and strain and tensile modulus of Buna-S rubber, Buna-S rubber embedded with base grain, and propellant. These studies will be used to determine beaker-to-beaker and within-grain variations.

Test conditions will be maintained so that each specimen and each grain will be subjected to similar loading. Scribed reference lines in conjunction with photographic techniques will be used to measure displacements.

These studies will be used to accumulate that information which is not available and is required for the stress analysis. Propellant characterization will be determined by the test methods and test specimens selected, and the differences will be noted in the properties of the case-bond system.

Typical characterization studies which may be necessary are:

(1) Buna-S rubber - tensile and elongation

(2) Buna-S rubber embedded with Epon 923 resin and CYH base grain - tensile and elongation

(3) Propellant

(a) Uniaxial tension

(b) Torsion

(c) Double lap shear

(d) Stress relaxation

2. <u>Failure Analysis Studies, Phase II</u>

These studies will be a continuation of uniaxial tension, simple torsion, double lap shear, and other multiaxial loading tests. The test specimens will be selected from the investigations in Phase I by the following criteria: (1) Reproducible specimen failed in the area of the case-bond resin; (2) location of failure can be predicted; e.g., resin to substrate, embedment granule to embedment resin, embedment granules cohesively, embedment granules to propellant, or propellant cohesively, (3) specimen geometry is adaptable to stress analysis, and (4) fabrication techniques are feasible and inexpensive.

Failure structural analysis studies will be performed on these specimens, and a general mechanism of multiaxial stress fields required to produce case-bond failure will be determined. The stress analysis of the case bond in the aft dome is dependent on a new finite element technique now being developed to better model the slotted region. From the elastic solution thus obtained, a viscoelastic stress-strain solution will be calculated for comparison with failure criteria developed from test results. No satisfactory analytical technique is available, or expected to be available, for stress analysis of the case bond in the vicinity of the TT port.

Test conditions will be maintained so that each specimen and each grain will be subjected to similar loading. The following conditions will be specified at the time samples are submitted for testing:

(a) Temperature

(b) Humidity

(c) Testing rate - tension

(d) Strain rate

(1) Lap shear

(2) Torsion

In addition to the measurements taken by the recording machine, displacements will be measured by scribed reference lines in conjunction with photographic techniques.

Specimens will be selected so that each specimen can be compared to each other specimen under the same type loading. Sample selection is shown in Table 2-41.

3. <u>Milestone</u>

The following schedule for this effort is provided as completion schedule:

CASE BOND	1965		1966								
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PRELIMINARY INVESTIGATION	Δ	▲									
SAMPLE PREPARATION		Δ		▲		Δ		▲			
TESTING				Δ		▲		Δ		▲	
FINAL ANALYSIS									Δ		▲

TABLE 2-41

SPECIMEN CONFIGURATION AND FABRICATION TECHNIQUES

Grain I		
Jackman Dogbone	Case-Bond Torsion	Modified Case-Bond Torsion
A1,A2,A9,A10 B1,B4,B6 C2,C5,C7,C8,C11,C12 D4,D7,D8,D11,D12 E1,E3,E5,E7,E9,E11 F2,F4,F6,F8,F10,F12	A3,A4,A11,A12 B2,B3,B5,B7,B8,B10,B11, B12 C1 D1,D2,D5,D9,D10 E2,E4,E6,E8,E10,E12 F1,F2,F5,F7,F9,F11	A5,A6,A7,A8 B9 C3,C4,C6,C9,C10 D3,D6

Grain II			
1/2 Jackman Dogbone	1/2 Case-Bond Torsion	Torsion	Lap Shear
B1 thru B12	B1 thru B12	A1,A5,A6, A7,A9,A11, A14,A15,A18	A2,A3,A4, A8,A10,A12 A13,A16,A17

Note: Grain II case-bond system is such that two samples are obtained at each location except for lap shear specimens.

Type Testing

Grain I				Grain II	
Tension	Torsion	Tension	Torsion	Scarf Joint	Lap Shear
B1 A8 F8	A1 B8 E7	B1 B2	B2 B1	A1,A5,A6	A2,A3,A4
C1 B9 F7	D1 A9 E8	B3 B4	B4 B3	A7,A9,A11	A8,A10,A12
A2 C9 E9	C2 B9 F10	B5 B6	B6 B5	A14,A15,A18	A13,A16,A17
D2 A10 E10	B2 C10 F9	B7 B8	B8 B7		
C3 D10 F12	D3 B10 E11	B9 B10	B10 B9		
D3 D11 F11	A3 D11 E12	B11 B12	B12 B11		
D4 B11	B4 A11		A1,A5,A6		
A4 D12	C4 C12		A7,A9,A11		
C5 A12	A5 B12		A14,A15,A18		
B5 E1	D5 F2				
A6 E2	B6 F1				
D6 F4	C6 E3				
C7 F3	D7 E4				
B7 E5	A7 F6				
D8 E6	C8 F5				

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SECTION XV

SPIRALLOY FAILURE CRITERIA STUDY

A. INTRODUCTION

The purposes of this study are to develop filament-wound shear specimens for determination of actual Minuteman Wing II case material shear strengths between various types of filament-wound layers and also develop failure criteria for case materials so that useful storage life of the Minuteman case can be predicted with reasonable accuracy by the use of less expensive token tests and/or subscale pressure vessels.

In order to obtain the maximum information and value from the Spiralloy Service Life Prediction Study (Chapter 3, Section VI), it will be necessary to perform development work on new types of interlaminar shear specimens (nonpressure vessel type) for the anisotropic material used in Minuteman cases. It will also be necessary to develop shear failure criteria for the case materials using these new types of shear tests.

Presently used shear testing procedures for filament-wound materials do not yield shear results which are typical of the interlaminar shear capability between the various types of wound layers used in Minuteman cases. New tests will be designed to establish basic shear values which can be used to predict Minuteman service life values for the Minuteman study. Shear capabilities between 14° helical-wound layers, 14° helical and level-wound layers, and 14° helical-wound layers and B-staged wafers will be determined. The relationships between material properties - resin content, void content, wafer B-stage condition, etc - and shear capability are also important and may be a link in establishing the failure criteria. A correlation of these relationships will be established to complete the study.

B. APPROACH

A failure criteria for the Minuteman case, which is considered to have mainly a dome shear type mode failure, will be necessary in order to be able to predict Minuteman case useful storage life by use of either subscale pressure vessels or token type shear specimens. A pure theoretical analysis is not possible with the present knowledge and capability. It is therefore necessary to perform a combined analysis using flexagage data from case hydrobursts and elastic property and interlaminar shear theories. The analysis will consist of the following procedure:

(1) Use high-speed movies to determine the locations of failures

(2) Determine by use of flexagages the strains through the dome material at the location where the majority of failures occur.

(3) Separate bending strains from axial strains.

(4) Using theoretical elastic modulii and measured strains for layers, calculate tensile and bending stresses in the various layers.

(5) Use theoretical analysis of orthotropic structure to determine interlaminar shear stresses in FSU's aft dome.

(6) Use previously determined layer tensile stresses to calculate the tensile loads in the various dome layers at burst pressure, and use these loads and the wafer areas over which they act to determine the theoretical layer-to-wafer failure shear strengths for FSU's.

(7) Design shear specimens and establish layer-to-layer shear strength as determined necessary from FSU analysis.

(8) Compare token test results with FSU analysis results for correlation. When correlations are established, token specimens can be stored to obtain shear degradation of the material and, therefore, of the Minuteman FSU case with age.

(9) Evaluate problems involved in use of 12-in. ovaloid wafer vessel for storage specimens. Establish basic value for hydroburst pressure of the wafer vessel.

(10) Establish correlations between wafer vessel test results, applicable token shear results, and FSU theoretical analysis results.

(11) Use the results obtained from (10) to determine the necessary minimum allowable shear strength for minimum allowable FSU burst capability.

C. TESTING

1. Sample Preparation

Material used for winding test specimens, Santa Clara 994 glass roving, ERL 2256 epoxy resin, and MPD Hardener, will be 100-percent inspected upon receipt and after completion of vessel winding of cylinder for all parameters as required in Minuteman material specifications HPC-133-08-2-15 and HPC-133-08-2-3. The materials used will meet the acceptance requirements of these specifications. In addition to specification acceptance testing, the following materials inspections will be made during sample preparation:

(a) Roving

(1) Characterization of finish by Pyrolysis technique

(2) Initial and periodic Clycol analysis of finish on roving

(b) Resin

(1) Characterization of each barrel of resin to be used by gas chromatography techniques

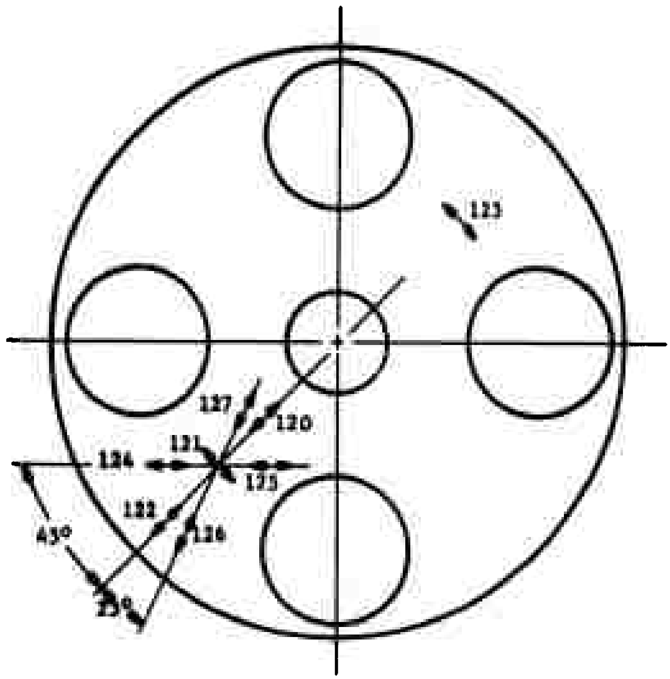
(2) Characterization of each barrel of resin to be used by refractive index techniques

(3) Periodic check of the resin stored in barrels for moisture content

(c) Hardener

(1) Characterization of each barrel of hardener by refractive index technique

(2) Periodic check of moisture content of each barrel of hardener



HORIZONTAL PROJECTION
FROM CASE CENTER LINE

GAGE NO.	DIRECTION	LOCATION
F 120	MERIDIAN	9.0°
F 121	HOOP	10.5°
F 122	MERIDIAN	12.5°
F 123	HOOP	10.5°
F 124	45°	13.5°
F 125	45°	8.5°
F 126	23°	13.5°
F 127	23°	8.5°

Figure 2-55. Flexagage Location for FSU Case Pressure Cycle Test

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SECTION XVII

IGNITER FAILURE CRITERIA DEVELOPMENT STUDY

A. INTRODUCTION

The existing igniter service life prediction study for the Minuteman stage III (D6) pyrogen igniter has been conducted for just over 3 yr with igniters being tested at scheduled intervals. The 11 surveillance igniters tested were stored at 70° F and ranged in age from 6 to 43 mo with one of these units performing outside the specification limit. Ballistic performance indicated no significant trends (at 95 percent confidence level) up to 2 yr; however, after the 3 yr tests, data indicated a significant decrease in maximum pressure and a significant increase in burn time as related to storage time. The fact that a trend has developed in test results is cause for concern, and the use of purchase specification limits as failure criteria is being questioned. The mathematical model chosen to represent the data was the linear regression model. Using this model and the igniter purchase specification limits as failure criteria, an extrapolation of the existing data permits a predicted service life value of 6 yr. Extrapolation of the 3-sigma limit placed about the mean time indicates that after 18 mo the confidence band exceeds the igniter burn time specification limit of 0.52 sec.[1]

This failure criteria development study will be conducted as indicated in the following steps:

(1) Step I - Establish a more accurate failure criteria by determining the use requirements or failure limit of the igniter and relate parameters measured from igniter static test results to these requirements

(2) Step II - Determine if the present linear mathematical model chosen to represent igniter test data is valid after igniter storage approaching 10 yr

(3) Step III - Determine the action required to more closely monitor aging trends

B. APPROACH

1. Step I

The system requirements of the stage III igniter, as defined by the model specification, is to attain 230 psi motor chamber pressure in less than 200 ms after initiation of firing current. This requirement is not directly measureable from a static test of the igniter assembly. The parameters related to the igniter purchase specification requirements are directly measureable from igniter static tests; therefore, these requirements in the past were used as failure criteria.

[1] Surveillance Quarterly Report, MTO-521-2, 20 October 1965

In order to relate igniter static test results to motor ignition transient (T_i), an analog computer program recently formulated will be used. This computer program can determine the mass flow properties required of an igniter to attain a given motor T_i. Using the ignition transient requirements of the Minuteman stage III motor of 200 ms, a critical mass flow will be determined for the existing igniter. (Mass flow is related to the igniter chamber pressure which is measureable from igniter static tests.) The present T_i of the 11 aged full-scale motor test is less than 100 ms. well within the 200 ms required, and shows no correlation with age.

To confirm this computer method, a minimum of four igniters will be fabricated; these igniters will be partially inhibited (Figure 2-56) to reduce the mass flow to the lower 3-sigma value expected after 10-yr storage, based on present trend curve information. Two of these igniters will be static tested to confirm that the proper amount of igniter propellant has been removed. One igniter will be retrofit in an aged motor and the motor static tested to confirm the computer program's ability in predicting critical mass flow. The motor used for this study may be selected from the operational surveillance study being conducted by OOAMA at the Lakeside test facilities. The Air Force will select the motor for this confirmation test. The remaining igniter will be held as backup. If the critical mass flow can be determined and confirmed, this will establish the failure criteria of igniter.

2. Step II

The predicted service life of the igniter presently is an extrapolation of the linear regression model chosen to represent the aging characteristics of the unit. An assumption is made that the actual aging characteristics maintain a linear relationship throughout the extrapolation. Aging characteristics are: Burn time (increasing) and maximum pressure (decreasing). Trends indicated by test results are primarily attributed to the same mechanism, migration of propellant ingredients into the cellulose acetate inhibitor which surrounds the cylindrical section of the igniter grain. Recently completed study of the Polaris (D-10) igniter indicates the NG migration rate is nonlinear. The D-10 and D-6 igniters are similar except for the grain configuration. The D-10 has a key slot arrangement, whereas the D-6 has a modified star arrangement. The critical factor, which is the initial performance of the modified star arrangement, may be more affected by NG migration than the key slot arrangement. If the rate of migration for the D-6 igniter is nonlinear, then the chosen mathematical model may not describe the function adequately, and resulting service life predictions would be erronious. To evaluate the validity of the chosen mathematical model and to become more knowledgeable of the igniter aging characteristics, a minimum of 13 igniters will be required. If the present linear model is invalid, the knowledge obtained from this study will be used to establish a mathematical model which describes the function more adequately. These new igniters will be stored at an elevated temperature of 120° F and tested periodically for periods up to 18 mo as shown in Table 2-42.

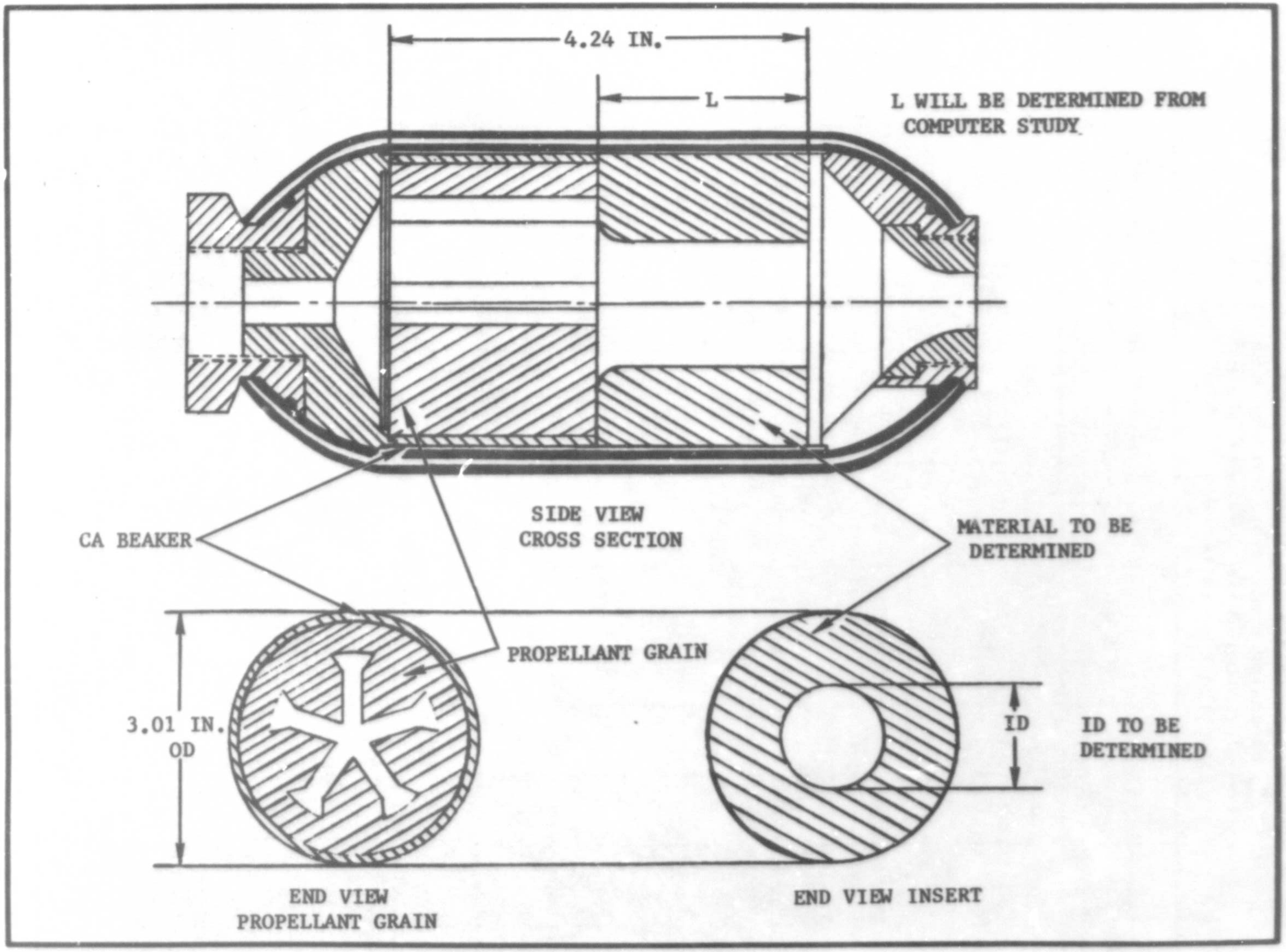

Figure 2-56. Detailed View of Inhibited Igniter

TABLE 2-42

IGNITER ACCELERATED AGING
TEST SCHEDULE

Igniter Test No.*	Zero Time**	Storage Temp (°F)	Test Sequence (mo)***				
			0	3	6	12	18
1	Oct 1966	amb	ab				
2	↑	120		ac			
3		120		ac			
4		120		ab			
5		120			ac		
6		120			ac		
7		120			ab		
8		120				ac	
9		120				ac	
10		120				ab	
11		120					ac
12	↓	120					ac
13	Oct 1966	120					ab

* Igniter S/N to be added upon receipt of igniters
** Zero Time is expected receiving date
*** Test Sequence:
a = Radiographic inspection
b = Gas sample and dissection followed by:
(1) Visual and dimensional inspection
(2) Profile study (three samples)
(3) Ignitability study (six specimens)
(4) Heat-of-reaction of pellets (six specimens)
(5) Strand burning rate study (six specimens)
(6) Heat of explosion of propellant (six specimens)
c = Static test at simulated altitude conditions

Due to the complexity involved in correlating high temperature storage test results to normal aging test results, the primary use of the results from this study will be to detect change in degradation rate. Results from the high temperature study will be compared to results of the normal aging study presently being conducted to detect a possible relationship.

Each igniter will be radiographically inspected in accordance with Specification HPC-133-02-5-2, General Requirements for Radiographic Inspection prior to dissection or static testing. Upon completion of the scheduled storage period two igniters will be static tested under simulated altitude conditions using the existing test changer (Kenvil drawing KD-7624). One igniter will be dissected per test period (Figures 2-57 and 2-58) and the following performed:

(a) Visual inspections and dimensional measurements of the grain to detect changes in propellant configuration or exudate formations will be made.

(b) Profile study will be conducted to detect chemical changes in the ingredients within the igniter. The propellant will be analyzed by the polarized microscopic method and the inhibitor and liner will be chemically analyzed per established procedures.

(c) Ignitability study (arc image) will be performed to determine changes in the ignition properties of the igniter grain. Section E (Figure 2-58) specimens will be machined without the normal water spray to prevent possible effects of water on the specimen surface.

(d) Section A will provide BKNO$_3$ pellets, to be tested for heat-of-reaction to determine changes in energy liberated due to storage or possible effects of migration of materials into the pellets.

(e) Strand burning rate tests to detect any change in burning rate with time will be conducted using specimens from Section E (Figure 2-58).

(f) The heat of explosion of the propellant removed from Section E (Figure 2-58) will be determined by use of a bomb calimeter to detect possible changes with age.

(g) A gas sample will be taken from the igniters to analyze for possible propellant decomposition products. This gas sample will be taken by inserting a hypodermic needle through the cork in the nozzle throat prior to dissection of the igniter.

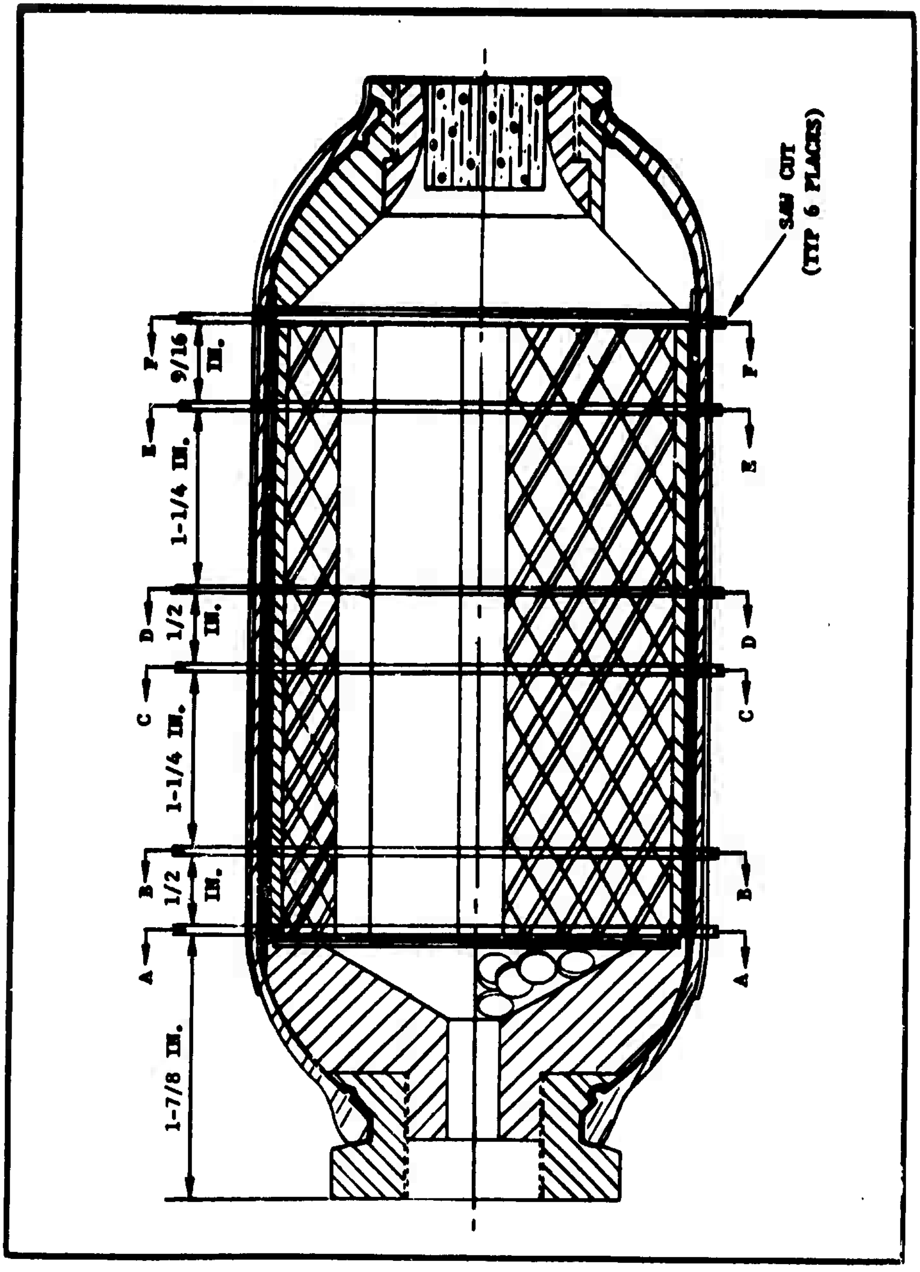

Figure 2-57. Detailed Igniter Grain Dissection

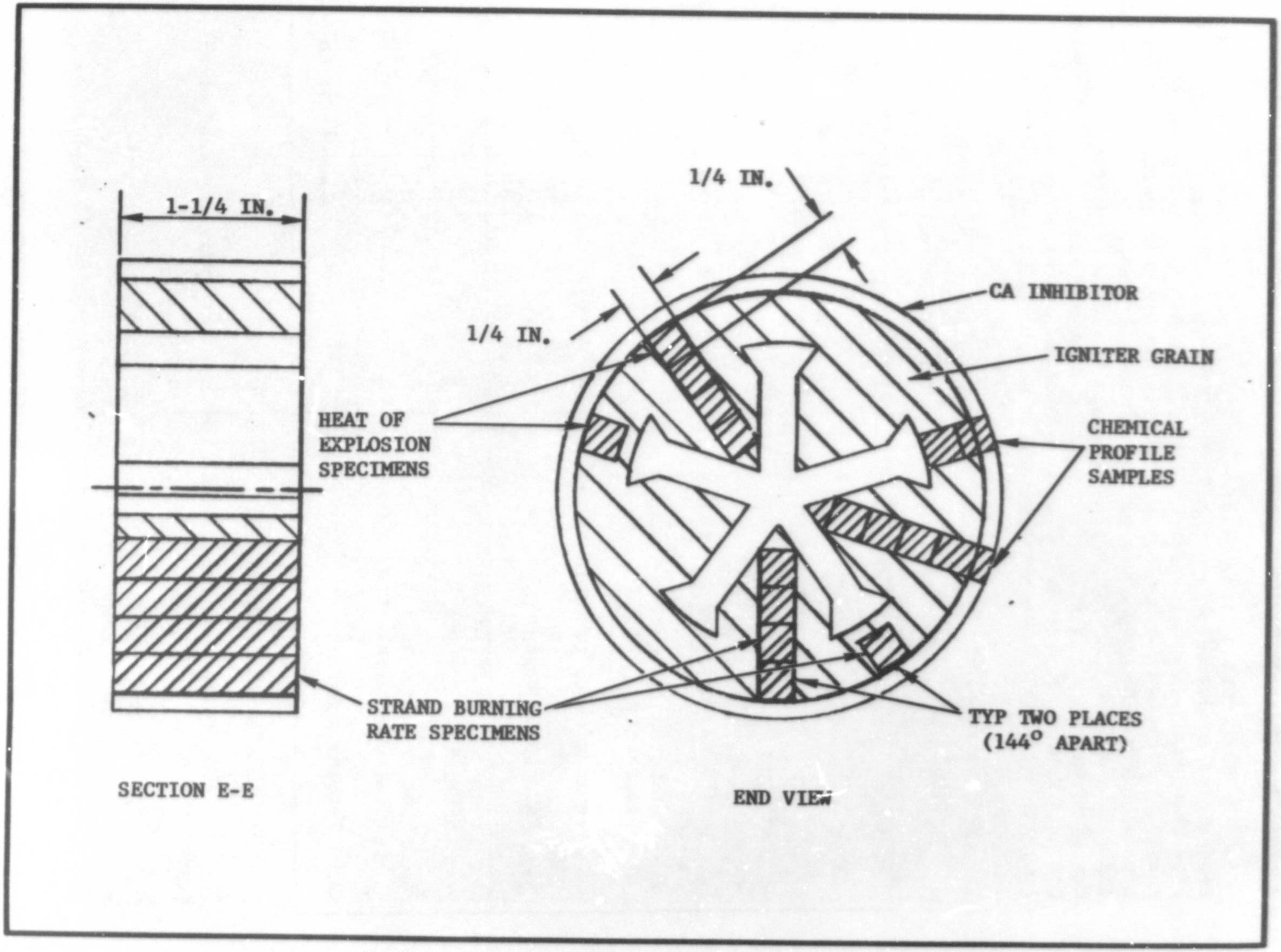

Figure 2-58. Detailed Igniter Sample Section

3. Step III

The existing igniter service life prediction study provides for tests to be conducted on an annual basis. The schedule was established when the program scope was extended from 5 to 10 yr. At that time, test results indicated no trends, justifying the annual test. Due to detected trends, the existing schedule will be condensed (Table 2-1). This rescheduling will reduce the 10 yr program to 7 yr; however, the program is supplemented by the operational recycle testing of igniters conducted by OOAMA. For this reason, the reduction in the duration of the study should not compromise the objectives of the igniter service life prediction study.

4. Milestones

The planned milestone schedule for this effort is as follows:

Task	1966 M	J	J	A	S	O	N	D	1967 J	F	M	A
Step I												
1. Establish failure criteria, computer program			Δ	—	Δ							
2. Inhibited igniter fabrication				Δ	—	Δ						
3. Igniter tests (inhibited)					Δ	Δ						
4. FSU static test							Δ					
Step II												
1. Procure igniters for high-temperature study				Δ	—	Δ						
2. Testing schedule						Δ	—	—	—	18 mo		—

5. Materials Requirements

The following list includes materials required to conduct this study:

(a) Partially inhibited igniters 4 each

(b) Pyrogen igniters (D-6) 13 each

Technical Operating Report
B O B Approval No.________

MOTOR STORAGE STUDIES PROGRAM PLAN

MTO-258-3A, REVISION 2

WEAPON SYSTEMS 133A AND B

15 January 1966
Changed 1 September 1966

Volume I

Contract Number AF 04(694)-544

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HERCULES INCORPORATED
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
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LIST OF EFFECTIVE PAGES (Volume I) 1 September 1966

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Page No.	Issue	Page No.	Issue
*Title	1 Sep 66	2-23 and 2-24	1 Jul 66
*A	1 Sep 66	*2-25 thru 2-29	1 Sep 66
*B	1 Sep 66	2-30	Original
*i	1 Sep 66	*2-31	1 Sep 66
ii thru viii	1 Jul 66	2-32 and 2-33	1 Jul 66
*ix	1 Sep 66	2-34 Blank	1 Jul 66
x thru xii	1 Jul 66	2-35 thru 2-37	Original
1-1 and 1-2	Original	2-38 thru 2-43	1 Jul 66
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1-4 and 1-5	Original	2-45 and 2-46	1 Jul 66
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1-11	Original	2-59	1 Jul 66
1-12	1 Jul 66	2-60	Original
1-13	Original	2-61	1 Jul 66
1-14	1 Jul 66	2-62	Original
*1-15	1 Sep 66	2-63	1 Jul 66
1-16 thru 1-20	1 Jul 66	2-64 and 2-65	Original
1-20A Added	1 Jul 66	2-66	1 Jul 66
1-20B Blank	1 Jul 66	2-67 thru 2-70	Original
1-21 and 1-22	1 Jul 66	2-71 and 2-72	1 Jul 66
1-23 thru 1-32	Original	2-73 thru 2-86	Original
1-33 and 1-34	1 Jul 66	2-87 and 2-88	1 Jul 66
1-35	Original	2-89	Original
1-36 Blank	Original	*2-90	1 Sep 66
2-1	1 Jul 66	2-91 thru 2-95	Original
2-2	Original	2-96 and 2-97	1 Jul 66
2-3	1 Jul 66	2-98 thru 2-101	Original
2-4	Original	2-102 Blank	Original
2-5 thru 2-7	1 Jul 66	2-103 and 2-104	Original
2-8 Blank	1 Jul 66	2-105	1 Jul 66
2-9 and 2-10	1 Jul 66	2-106	Original
2-11	Original	2-107	1 Jul 66
2-12	1 Jul 66	2-108 Blank	1 Jul 66
2-13 and 2-14	Original	2-109	Original
2-15	1 Jul 66	2-110	1 Jul 66
2-16 Blank	1 Jul 66	*2-111	1 Sep 66
2-17 and 2-18	Original	2-112 thru 2-115	Original
2-19 thru 2-21	1 Jul 66	*2-116	1 Sep 66
2-22	Original	2-117	1 Jul 66

Page No.	Issue
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2-119 and 2-120	1 Jul 66
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2-126 thru 2-129	Original
*2-130	1 Sep 66
2-131 thru 2-133	Original
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2-161 thru 2-164	1 Jul 66
2-164A thru 2-164K Added	1 Jul 66
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2-165 and 2-166	1 Jul 66
*2-167 thru 2-170	1 Sep 66
*2-170A Added	1 Sep 66
*2-170B Blank	1 Sep 66
2-171 and 2-172	Original
2-173	1 Jul 66
2-174 and 2-175 Added .	1 Jul 66
*2-176	1 Sep 66
2-177 thru 2-180 Added .	1 Jul 66

Report No. MTO-258-3A, Rev 2, Change 2

Copy No. 4

Date 1 September 1966

MOTOR STORAGE STUDIES PROGRAM PLAN
WEAPON SYSTEMS 133A AND B

Volume I

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FOREWORD

This document presents the Motor Storage Studies Program Plan and the Hercules plan for development of failure criteria.

The original authority and requirements for motor storage studies were established in Contract AF 04(647)-243, Exhibit B, paragraph III.F.5, and Exhibit D, Section III, paragraph D.9; and as amended by CCN's No. 108, 165, and 200.

Authority for continuation of the motor storage program from 1 July 1963 thru 30 June 1965 is given in Contract AF 04(694)-127, Exhibit A, paragraph D.9, as amended by CCN's 201, 208, and 269.

Authority for continuation of the motor storage program from 1 July 1965 thru 30 September 1966 is given in Contract AF 04(694)-544, Exhibit A, part VII, paragraph C, as amended by CCN No. 50.

This document supersedes MTO-258-3A, Revision 1, Motor Storage Studies Program Plan, dated 1 December 1964, and is presented in two volumes. Volume I contains the effort which was transferred from Air Force Systems Command (AFSC) to Air Force Logistics Command (AFLC) in the transfer of engineering responsibility of Wing I thru Wing V. Each test schedule indicates the effort remaining as of transfer date, 1 October 1966. Volume II contains the effort which is the responsibility of Air Force Systems Command (full-scale unit effort and materials unique to Operational Reliability Improvement (OPRI)).

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General Services Department
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LIST OF FIGURES (Cont)

LIST OF TABLES

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Component or Material	Type Test	No. of Specimen Placed in Storage	1960												1961											
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Igniter	Temp cond, functional	37																								
	Transportation cond, x-ray																									
	Flt cond, x-ray, funct, static fire																									
	Flight cond, x-ray, dissect																									
	X-ray																									
Failure criteria study	Static test and dissection	17																								
Igniter S & A	Temp cond, functional	28																								
	Transportation cond, electrical																									
	Flt cond, functional, static fire																									
Pellets	Physical & chemical on "new" pellets																									
	Physical & chemical on "old" pellets																									
TT switch -5	Transportation vibration, electrical	11																								
-5	Flight cond, functional, destruct																									
-9	Transportation vibration, electrical	11																								
-9	Flight cond, functional, destruct																									
-11	Transportation vibration, electrical	24																								
-11	Flight cond, functional, destruct																									
Frangible sectors Wing I	Transportation vibration electrical	120												11												34
	Flight vibration																									3
Wing II	Transportation vibration electrical	152																								
	Flight vibration																									
Nozzles Wing I	Pressure leak, cold torque, NDT	16																								
	Mechanical cycle																									
	X-ray, disassemble																									
	Hand cycle																									
Wing II	Pressure leak, cold torque, NDT	7																								
	X-ray, disassemble																									
	Hand cycle																									
Spiralloy																										
Wafer lap shear, Type 1 (cyl)	Physical	260																								
Layer lap shear, Type 1 (cyl)	Physical	400																								
Wafer lap shear, Type 1 mat (cyl)	Physical																									
Layer lap shear, Type 2 (cyl)	Physical																									
Wafer bottles	Hydroburst	21																								
Ovaloid bottles	Hydroburst	40																								
Short beam shear (lab)	Physical	704																								
Uncoated NOL rings	Physical	440																								
Coated NOL rings	Physical	72																								
FSU cases, Wing I	Hydroburst	6																								
FSU LS & SBS, Wing I	Physical	272																								
FSU cases, Wing II	Hydroburst	2																								
FSU LS & SBS, Wing II	Physical	368																								
Failure criteria study																										
Interlaminar shear ring I	Physical	504																36	36	36			36			36
Interlaminar shear ring II	Physical	440																								
Propellant	Chemical	30																								
	Physical	1855												16	32	24	56	56	24	32	32		56	24	16	24
	Subscale static	109			1			2	2	1	3	2	1	5	4	1	4	3	1	6	4	1	4	3	1	4
Failure criteria study																										
FSU Grain Dissection																										

TABLE 1-1A

MASTER SURVEILLANCE TEST SCHEDULE

1961								1962												1963												1964												1965											
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
																		21																																					
																																		1		4	2	3																3	2
																																				3				2														2	
																																											1											
																																											2		6									
																		21																																					
																																		1		4	2	3						1										3	2
																																				3				2				2		6								2	
																2			8			8			8			8			8			8			8			8						8						8			
																																											1											
																							5												2												2								
																																			2												2								
																										6											2											1					
																																						2											2					
																																														24								
							34			3		10			10		11		69			2	1	8			9		11		73			2		7			8		9		69			1		6			7		9		60
							3												4					2				6	1				1			1	4			1	2				1			1	3						6
																		112												136												120												104	
																											8			8						8						8						8						8	
																				16						4						8						4						8						4					
																										2						4						2						4						2				2	
																										8						8						8						8						8				2	
																																										7												
																																																				1	
																																																7						6
																								10						5						5						5						5						5	
																												32			32			32			32			32			32			32			32			32			32
																												20			20			20			20			20			20			20			20			20			20
																																																	8					
																																										1												
	36			36			36			36			36			36			36			36			36			36			36																			36						
																							50			50			50			50			50			50			50			50						40						
4	32	32		56	24	16	24	16	8	24	16		24	8		24	8	8	24	8		24	8		24			16			16																		2						2
1	6	4	1	4	3	1	4	3	1	4	4	1	3	3	1	6	4	1	4	3	1	4	3	1	2			4			2			2 (10 FPC held for backup)															171						149
																																												1			1	1	1			1	

Component or Material	Type Test	No. of Specimen Placed in Storage	1966												1967												
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Igniter	Temp cond, functional	37																									
	Transportation cond, x-ray		3										2	2	3											2	3
	Flt cond, x-ray, funct, static fire		1			3									1				2				1		1		
	Flight cond, x-ray, dissect		1						1								1						1				
	X-ray														3	1	3		3								
Failure criteria study	Static tests and dissection	17											3	1		3			3						3		
Igniter S & A	Temp cond, functional	28																									
	Transportation cond, electrical		3										2	2	3											2	3
	Flt cond, functional, static fire		1			3									1				2				1		1		
Pellets	Physical & chemical on "new" pellets				8						8						8						8				
	Physical & chemical on "old" pellets		1						1								1						1				
TT switch -5	Transportation vibration, electrical	11																									
-5	Flight cond, functional, destruct					1																					
-9	Transportation vibration, electrical	11																									
-9	Flight cond, functional, destruct								2																		
-11	Transportation vibration, electrical	24				9												12									
-11	Flight cond, functional, destruct					2												2									
Frangible sectors Wing I	Transportation vibration, electrical	120					3					9		58										8		47	
	Flight vibration			6	1		4			1				2				1	3	5						6	
Wing II	Transportation vibration, electrical	152											88												72		
	Flight vibration						8						8						8						8		
Nozzles Wing I	Pressure leak, cold torque, NDT	16	8						4						8						4						8
	Mechanical cycle		4						2						4						2						4
	X-ray, disassemble																										1
	Hand cycle		6						6						6						6						6
Wing II	Pressure leak, cold torque, NDT	7																									
	X-ray, disassemble																										
	Hand cycle							6						6						6						6	
Spiralloy																											
Wafer lap shear, Type 1 (cyl)	Physical	260																		28							
Layer lap shear, Type 1 (cyl)	Physical	400												28						28						28	
Wafer lap shear, Type 1 mat (cyl)	Physical																										
Layer lap shear, Type 2 (cyl)	Physical																										
Wafer bottles	Hydroburst	21														3											
Ovaloid bottles	Hydroburst	40					5																				
Short beam shear (lab)	Physical	704			32			32			32						32						32				
Uncoated NOL rings	Physical	440			20			20			20						20						20				
Coated NOL rings	Physical	72	8						8						8						8						8
FSU cases, Wing I	Hydroburst	6	1	1					1						1												1
FSU LS & SBS, Wing I	Physical	272	48	32											32						16						32
FSU cases, Wing II	Hydroburst	2																						1			
FSU LS & SBS, Wing II	Physical	368	8	8					8	8					8	8					8	8		16			8
Failure criteria study																											
Interlaminar shear ring I	Physical	504																									
Interlaminar shear ring II	Physical	440																									
Propellant	Chemical	30						2						2	12					2						2	12
	Physical	1855	28					208	84					112						55						84	84
	Subscale static	109																									
Failure criteria study																											
FSU Grain Dissection																											1	

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

	1967							
	M	J	J	A	S	O	N	D
								2
	2				1		1	
					1			
	1							
	3						3	
								2
	2				1		1	
					8			
					1			
						8		47
1	3	5						6
							72	
	8						8	
			4					
			2					
			6					
		6						6
		28						
		28						28
					32			
					20			
			8					
			16					
						1		
			8	8		16		
		2						2
		55						84
								1

1968											
J	F	M	A	M	J	J	A	S	O	N	D
3											1
				1		1				1	1
		1						1			
					3						
				3 (1 unit held for backup)							
3											1
				1		1				1	1
		1						1			
			7								
			2								
									5		37
					6				3		4
										56	
				8						8	
8						4					
4						2					
1											
6						5					
					6						6
					28						
					28						28
	3										
		32						32			
		20						20			
8						8					
1											
32	16										
8	8					8			16		
12					2						2
84						28					

1969											
J	F	M	A	M	J	J	A	S	O	N	D
2											
						2		1			2
		1						1			
2											
						2		1			2
		1						1			
			9								
			3								
									2		20
					11				3		6
										40	
				8						8	
8						4					
4						2					
1											
5						4					
											1
					6						6
					28						
					28						28
	3										
								32			
								20			
						8					
32											
									1		
8	8								32		
					2						2
84						28					

1970											
J	F	M	A	M	J	J	A	S	O	N	D
1											
				2		1					
1											
				2		1					
			5								
			2								
									1		
					12				1		8
										24	
				8						8	
8						4					
4						2					
1											
4						3					
											1
					5						5
					28						
					28						28
	3										
								32			
								20			
						8					
16											
8	8								16		
					2						2
84						28					

1971											
J	F	M	A	M	J	J	A	S	O	N	D
			6								
			3								
			1								
										12	
				6						6	
8						4					
4						2					
1											
3						2					
											1
					4						4
					28						
					28						
	3										
								32			
								20			
16	16										
									16		
					2						2

Component or Material	Type Test	No. of Specimen Placed in Storage	1972												1973												
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Igniter	Temp cond, functional	37																									
	Transportation cond, x-ray																										
	Flt cond, x-ray, funct, static fire																										
	Flight cond, x-ray, dissect																										
	X-ray																										
Failure criteria study	Static test and dissection	17																									
Igniter S & A	Temp cond, functional	28																									
	Transportation cond, electrical																										
	Flt cond, functional, static fire																										
Pellets	Physical & chemical on "new" pellets																										
	Physical & chemical on "old" pellets																										
TT switch -5	Transportation vibration, electrical	11																									
-5	Flight cond, functional, destruct																										
-9	Transportation vibration, electrical	11																									
-9	Flight cond, functional, destruct																										
-11	Transportation vibration, electrical	24				3												3									
-11	Flight cond, functional, destruct					2												3									
Frangible sectors Wing I	Transportation vibration, electrical	120																									
	Flight vibration																										
Wing II	Transportation vibration, electrical	152																									
	Flight vibration						6						6														
Nozzles Wing I	Pressure leak, cold torque, NDT	16	8						4						8												
	Mechanical cycle		4						2						4												
	X-ray, disassemble		1												9												
	Hand cycle		2						1						1												
Wing II	Pressure leak, cold torque, NDT	7																									
	X-ray, disassemble													1												1	
	Hand cycle							3						3						2						2	
Spiralloy																											
Wafer lap shear, Type 1 (cyl)	Physical	260						24												24							
Layer lap shear, Type 1 (cyl)	Physical	400						24												24							
Wafer lap shear, Type 1 mat (cyl)	Physical																										
Layer lap shear, Type 2 (cyl)	Physical																										
Wafer bottles	Hydroburst	21		3												3											
Ovaloid bottles	Hydroburst	40																									
Short beam shear (lab)	Physical	704									32												32				
Uncoated NOL rings	Physical	440									20												20				
Coated NOL rings	Physical	72																									
FSU cases, Wing I	Hydroburst	6																									
FSU LS & SBS, Wing I	Physical	272														16											
FSU cases, Wing II	Hydroburst	2																									
FSU LS & SBS, Wing II	Physical	368										32															
Failure criteria study																											
Interlaminar shear ring I	Physical	504																									
Interlaminar shear ring II	Physical	440																									
Propellant	Chemical	30						1						1													
	Physical	1855																									
	Subscale static	109																									
Failure criteria study																											
FSU Grain Dissection																											

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1973								1974												1975												1976												1977											
M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
											1 2												3																																
	2						1 2						1						1 1																			:																	
	24 24			32 20									24 24												24 24												24 24																		

	Type Test	No. of Specimen Placed in Storage	1960												1961												
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Propellant-to-liner bond FSU I	Physical & chemical	180																									
	Physical & chemical	8																									
FSU II	Physical & chemical	186																									
	Physical & chemical	8																									
ailure criteria study Case bond system No. 1	Physical	36		4	8	8	8			8																	
2		36		4	8	8	8			8																	
3		34		4	6	8	8			8																	
4		60		4	8	8	8			8			4			4			4			4			4		
5		56		4	8	8	8			8			4			4			4			4			4		
6		60		4	8	8	8			8			4			4			4			4			4		
7		27						2	2	2	3			2			3			2			3			2	
9		120												6	8	8	8			8			8			8	
10		59						3	4	4	4			4			4			4			4			4	
11		81												6	6	6	6			6			6			6	
12		84													6	6	6			6			6			6	
13		172																									
15	(BSD Effort)	128																									
17	(BSD Effort)	120																									
18	(BSD Effort)	120																									
19	(BSD Effort)	248																									
20		135																									
21	(BSD Effort)	141																									
22	Physical (BSD Effort)	138																									
Internal Insulator FSU I	Physical	96																									
	Subscale static (Erosion)	23																									
FSU II	Physical	48																									
	Subscale static (Erosion)	8																									
Failure criteria study RPD 150 Phenolic	Physical	99									9			9			9			9			9			9	
Buna N	Physical	92																									
Buna S	Physical	483																									
External Insulation Avcoat	Physical	354																									
Cork	Physical	2880																									
	Fungus	240																									
Pressure Seal	Physical	3884							48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Elastomer	Physical	380								20			40			40			40			40			40		
Greases	Physical	46									2	4	4			4			4			4			4		
Adhesive and Potting Compound J 1170-E18	Physical	176																									
A 12 T		176																									
934		176																									
DCQ-9-0024		88																									
937.2		88																									
RTV77		88																									
RTV88		88																									
923		176																									
C-7		176																									
Thixon CB2		88																									
C-7/SBR 80/20		240																									
C-7/SBR 60/40		240																									
C-7/NBR 80/20		240																									
C-7/NBR 60/40		240																									
923.2/SBR	(BSD Effort)	240																									
923.2/NBR	(BSD Effort)	240																									
B-1 Fix/BPC No. 1	Physical	44																									
CYH/BPC No. 1	Chemical	66																									
B-1 Fix/BPC No. 2	Physical (BSD Effort)	44																									
948.2/953	Physical (BSD Effort)	176																									
948.2/SBR	Physical (BSD Effort)	264																									
948.2/SBR	Peel (BSD Effort)																										
Boot-to-flap	Peel (BSD Effort)																										
FSU Motors Wing I	Static fire	17																								1	
Wing II	Static fire	6																									
Wing IV	Static fire	4																									
Wing VI	Static fire (BSD Effort)	2																									

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1961							1962												1963												1964												1965											
J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
																																																	18					18
																																																	1					1
																																																	18					18
																																																	1					1
		4			4			4																																														
		4			4																																																	
		4			4			4																																														
2			3			2			3			3																																										
8			8			8			8			8			8			8			8			8			4			4																							
4			4			4			4			4			4			4			4			4																														
6			6			6			6			6			6			6			6			6			3																											
6			6			6			6			6			6			6			6			6			6																											
																							16			8			8			8			8			8			16			8			16						16	
													16			8			8			8			8			8		16			8			16						8						8					
																							8			8			8			8			8						8													
																							8			8			8			8			8						8													
																																																					16	
																																						6			3			6			3			1			3	
																																																6	6					6
																																																		2				
																																																6						6
																																																	1					
9			9			9			9			9			9						9						9																											
								12			8			8			8			8			8			8			8			8						8						8										
																												50			5			22			10			22			13			22			13			22		
														39			24			29			29			34			24			34			24			34			10			29			5			39				
																														240			240			240			240			240			120			120			120			
																												16			16			16			16			16			16			16			16			16			
48	48	48	48	48	48	48	48	48	48	48	48	48	48	48		48	48	48	48		48	48		48	48			48			48														30	30	30	30	30	30	30	30	30	30
		40			40			40			40			40						40																																		
		4			4			4			4			4						4						4																												
																																				16						8						16						8
																																				16						8						16						8
																																				16						8						16						8
																																				8						4						8						4
																																				8						4						8						4
																																															8						4	
																																															8						4	
																																						8					8	4						4	8				
																																						16						8						16				
																																																					8	
																																															4						4	
																																								4						6						6		
																																																					4	
						1			1			1				1			1			1				1										1						1											1	
																																															1							

	Type Test	No. of Specimen Placed in Storage	1966												1967													
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Propellant-to-liner bond FSU I	Physical & chemical	180						6						18						6						18		
	Physical & chemical	8												1												1		
FSU II	Physical & chemical	186						6						18						6						18		
	Physical & chemical	8												1												1		
Failure criteria study, Case bond system No. 1	Physical	36																										
2		36																										
3		34																										
4		60																										
5		56																										
6		60																										
7		27																										
9		120																										
10		59																										
11		81																										
12		84																										
13		172					8												8						8			
15	(BSD Effort)	128	8					Hold 8 specimens for backup																				
17	(BSD Effort)	120						Hold 72 specimens for backup																				
18	(BSD Effort)	120						Hold 72 specimens for backup																				
19	(BSD Effort)	248		16			16			16						16						16						16
20		135		6			3			6						6						6						6
21	(BSD Effort)	141			6				Hold 135 specimens for backup																			
22	Physical (BSD Effort)	138				3			6			3			6			3			6			3			6	
Internal Insulator FSU I	Physical	96	6					6	6					6	6					6	6						6	
	Subscale static (Erosion)	23		2						2				1		2				1		1				1		1
FSU II	Physical	48												6												6		
	Subscale static (Erosion)	8							1												1							
Failure criteria study RPD 150 Phenolic	Physical	99																										
Buna N	Physical	92																										
Buna S	Physical	483				16						22						16						22				
External Insulation Avcoat	Physical	354																										
Cork	Physical	2880			120						120						120						120					
	Fungus	240				16						16												16				
Pressure Seal	Physical	3884	30	30	30	30	30	30	30	30	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Elastomer	Physical	380																										
Greases	Physical	46																										
Adhesive and Potting Compound J 1170-E18	Physical	176						16						8						16						8		
A 12 T		176						16						8						16						8		
934		176						16						8						16						8		
DCQ-9-0024		88						8						4						8						4		
937.2		88						8						4						8						4		
RTV77		88					8						4						8						4			
RTV88		88					8						4						8						4			
923		176	8	4					4	8					8	4					4	8					8	4
C-7		176		8						16						8						16						8
Thixon CB2		88					4						8						4						8			
C-7/SBR 80/20		240					12						24						12						24			
C-7/SBR 60/40		240					12						24						12						24			
C-7/NBR 80/20		240					12						24						12						24			
C-7/NBR 60/40		240					12						24						12						24			
923.2/SBR	(BSD Effort)	240					12						24						12						24			
923.2/NBR	(BSD Effort)	240					12						24						12						24			
B-1 Fix/BPC No. 1	Physical	44					4						4						4						4			
CYH/BPC No. 1	Chemical	66				6						6						6										
B-1 Fix/BPC No. 2	Physical (BSD Effort)	44					4						4						4						4			
948.2/953	Physical (BSD Effort)	176			16						8						16						8					
948.2/SBR	Physical (BSD Effort)	264			24						12						24						12					
948.2/SBR	Peel (BSD Effort)	264					24						12						24						12			
Boot-to-flap	Peel (BSD Effort)	132								12						6						12						6
FSU Motors Wing I	Static fire	17						1						1											1			
Wing II	Static fire	6			1											1												1
Wing IV	Static fire	4											1															
Wing VI	Static fire (BSD Effort)	2																										

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

						1968												1969												1970												1971											
J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
					18						6						18						6						18						6						18						6						18
					1												1												1												1												1
					18						6						18						6						18						6						18						6						18
					1												1												1												1												1
				8						8						8						4						8												4						4							
	16						16						16						16						16						16						8						8						8				
	6						6						6						6						6						6						6						6						6				
6			3			6			6						6						6						6						6						6						6						6		
6						6						6						6																														6						6
	1				1		1				1		1					1	1					1						1						1														1				
					6												6												6												6												6
1												1												1												1												1					
			22						16						22						16						22						16						22						16						22		
		120						120						120												120												120												120			
			16												16																																						
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
					8						16						8						16												8												8						
					8						16						8						16												8												8						
					8						16						8						16												8												8						
					4						8						4						8												4												4						
					4						8						4						8												4												4						
				4						8						4						8						4						8												4							
				4						8						4						8						4						8												4							
4	8					8	4					4	8					8	4					4	8					8							4					4							4				
	16						8						16						8						16												8												8				
				8						4						8						4						8						4						8												4	
				24						12						24						12						24						12						24												12	
				24						12						24						12						24						12						24												12	
				24						12						24						12						24						12						24												12	
				24						12						24						12						24						12						24												12	
				24						12						24						12						24						12						24												12	
				24						12						24						12						24						12						24												12	
				4						4						4						4						4						4																			
									6						6						6						6						2																				
				4						4						4						4						4						4						4													
		8						16						8						16						8						16						8						16									
		12						24						12						24						12						24						12						24									
				12						24						12						4						12						24						12						24							
	12						6						12						6						12						6						12						6										
				1						1						1								1									1																				
							1												1											1																						
																1												1												1													
											1																								1																		

	Type Test	No. of Specimen Placed in Storage	1972 J	F	M	A	M	J	J	A	S	O	N	D	1973 J	F	M	A	M	J	J	A	S	O	N	D	1974 J	F
Propellant-to-liner bond FSU I	Physical & chemical	180																										
	Physical & chemical	8																										
FSU II	Physical & chemical	186						6																				
	Physical & chemical	8																										
Failure criteria study Case bond system No. 1	Physical	36																										
2		36																										
3		34																										
4		60																										
5		56																										
6		60																										
7		27																										
9		120																										
10		59																										
11		81																										
12		84																										
13		172																										
15	(BSD Effort)	128																										
17	(BSD Effort)	120																										
18	(BSD Effort)	120																										
19	(BSD Effort)	248		8						8						8						8						8
20		135		6						6						6						6						6
21	(BSD Effort)	141																										
22	Physical (BSD Effort)	138				6						6						6						6				
Internal Insulator FSU I	Physical	96												6														
	Subscale static (Erosion)	23		1												1												
FSU II	Physical	48																										
	Subscale static (Erosion)	8							1																			
Failure criteria study RPD 150 Phenolic	Physical	99																										
Buna N	Physical	92																										
Buna S	Physical	483				16						22						16						22				
External Insulation Avcoat	Physical	354																										
Cork	Physical	2880									120												120					
	Fungus	240																										
Pressure Seal	Physical	3884	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Elastomer	Physical	380																										
Greases	Physical	46																										
Adhesive and Potting Compound J 1170-E18	Physical	176						8												8								
A 12 T		176						8												8								
934		176						8												8								
DCQ-9-0024		88						4												4								
937.2		88						4												4								
RTV77		88					4												4									
RTV88		88					4												4									
923		176	4							4					4							4					4	
C-7		176								8												8						
Thixon CB2		88										4													4			
C-7/SBR 80/20		240										12													12			
C-7/SBR 60/40		240										12													12			
C-7/NBR 80/20		240										12													12			
C-7/NBR 60/40		240										12													12			
923.2/SBR	(BSD Effort)	240										12													12			
923.2/NBR	(BSD Effort)	240										12													12			
B-1 Fix/BPC No. 1	Physical	44										12													12			
CYH/BPC No. 1	Chemical	66																										
F-1 Fix/BPC No. 2	Physical (BSD Effort)	44																										
948.2/953	Physical (BSD Effort)	176			8												8											
948.2/SBR	Physical (BSD Effort)	264			12												12											
948.2/SBR	Peel (BSD Effort)	264						12											12									
Boot-to-flap	Peel (BSD Effort)	132		6												6												6
FSU Motors Wing I	Static fire	17																										
Wing II	Static fire	6																										
Wing IV	Static fire	4																										
Wing VI	Static fire	2																										

TABLE 1-1A (Cont)

MASTER SURVEILLANCE TEST SCHEDULE

1973								
A	M	J	J	A	S	O	N	D
				8				
				6				
6						6		
16						22		
					120			
[illegible]	6	6	6	6	6	6	6	6
		8						
		8						
		8						
		4						
		4						
	4							
	4							
				4				
				8				
							4	
							12	
							12	
							12	
							12	
							12	
							12	
							12	
	12							

1974											
J	F	M	A	M	J	J	A	S	O	N	D
	8						8				
	6						6				
			6						6		
6	6	6	6	6	6	6	6	6	6	6	6
					8						
					8						
					8						
					4						
					4						
				4							
				4							
4							4				
							8				
										4	
										12	
										12	
										12	
										12	
										12	
										12	
										12	
		8									
		12									
				12							
	6										

1975											
J	F	M	A	M	J	J	A	S	O	N	D
			6						6		
6	6										
				4							
				4							
4											
										4	
										12	
										12	
										12	
										12	
										12	
										12	
										12	
		8									
		12									
				12							
	6										

1976											
J	F	M	A	M	J	J	A	S	O	N	D
	1										
		8									
		12									
				12							
	6										

1977											
J	F	M	A	M	J	J	A	S	O	N	D

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TABLE 1-5 (Cont)

TEST PARAMETERS

Test Item	Parameter	Data Used for Service Life Predictions
Case		
Tensile shear specimens	Interlaminar shear(3)	X
	Short beam shear(4)	X
	Lap shear	X
	Hoop tensile	--
Wafer bottles	Burst pressure	--
FSU cases	Burst pressure	--
Internal insulation		
Rubber	Tensile	--
	Elongation(5)	X
	Density	--
	Hardness	--
	Erosion(5)	X
	NG migration	--
Phenolic	Tensile	--
	Hardness	--
	Elongation	--
	Erosion	X
External insulation		
Avcoat	Tensile	--
	Elongation	--
	Hardness	--
Cork	Tensile	--
	Hardness	--
	Elongation	--
	Density	--

(3) Current failure criteria values = 50 percent degradation of initial value

(4) Current failure criteria val[illegible] = 40 percent degradation of initial data (based on case design [illegible]y factor and evaluation of test results of failure criteria studies)

(5) Current failure criteria values = 3.5 percent elongation (based on hydroburst data on allowable case expansion) and 25 percent increased erosion (based on evaluation of full scale motor erosion data)

TABLE 1-5 (Cont)

TEST PARAMETERS

Test Item	Parameter	Data Used For Service Life Predictions
Propellant grain	Maximum stress	X
	Strain at max stress	X
	Maximum strain	X
	Stress at max strain	X
	Creep	--
	Relaxation modulus	--
	Chemical changes	X
	Accumulative damage	--
Case bond	Tensile	X
	Peel	--
	Chem profile	X
Adhesives and potting compounds	Tensile	--
	Elongation	--
	Hardness	--
	Peel	--
	Shear	--
	Chemical changes	--

There are many tests and observations made in the Laboratory Support Program which do not provide measurable data. This type of information is recorded by photographs or other means and used in making predictions and performing failure analyses.

The procedure for analyzing and interpreting data has been designed to establish a consistent method for making service life predictions. The procedure is outlined in the following paragraph.

c. Service Life Estimating Procedure

1) Introduction

The minimum service life of motors in the Minuteman propulsion system is normally considered to be the demonstrated storage life determined by the oldest successful full-scale motor firing. However, only limited confidence can be placed on a single motor test. Also, because of the small sample size, minor configurational differences, and the relatively short lead time of the storage motors over the operational force, data from

SECTION IV

FRANGIBLE SECTOR SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The Wing I frangible sector is illustrated in Hercules drawing No. 2045BU. The Wings II through VI frangible sector is illustrated in Hercules drawing No. 01A00545-001. This study applies to both types of frangible sectors. A portion of the Wing I sectors were of R & D design, and the wire shielding was not connected to the sector body. As a result of this condition, the leads into the sector body broke when vibrated excessively. This design was not used on operational motors.

The frangible sectors will be tested to determine the interactions of time, temperature, and humidity over a period of 10 years. The frangible sectors will be conditioned to simulate actual operational conditions. Transportation vibration simulates the expected motor transportation. Operational vibration simulates the expected vibration received during flight.

B. DETAILED TEST PLAN

1. Acquisition of Samples

A total of 128 Wing I frangible sectors, manufactured by Librascope Inc, and 160 Wings II through VI frangible sectors, manufactured by Hercules Incorporated, Port Ewen Plant (HI/PE), were procured for this study.

2. Storage

Upon completion of initial inspection and transportation vibration, the frangible sectors were stored under the following conditions:

No. and Type	Storage Conditions
32 Wing I frangible sectors	100° F, 70% rh
32 Wing I frangible sectors	100° F, 10% rh
40 Wings II - VI frangible sectors	100° F, 70% rh
40 Wings II - VI frangible sectors	100° F, 10% rh
32 Wing I frangible sectors	70° F, 70% rh
32 Wing I frangible sectors	70° F, 10% rh
40 Wings II - VI frangible sectors	70° F, 70% rh
40 Wings II - VI frangible sectors	70° F, 10% rh

Removal from storage for testing and conditioning is as scheduled in Tables 2-4 through 2-9.

TABLE 2-4

FRANGIBLE SECTORS TEST SCHEDULE, WING I
(Storage Conditions: 70° F, 10 percent rh)

Sector Ser No. 10% rh	Storage Date	Zero Time Date**	Test Sequence (mo from zero time)* 0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
1817	Jun 63	Dec 62	a	c																			
565	Jun 63	Mar 62																					
738	Jun 63	Aug 62																					
1819	Jun 63	Dec 62	a		b	c																	
656	Jun 63	May 62																					
742	Jun 63	Aug 62																					
610	Jun 63	Mar 62	a		b		b	c															
736	Jun 63	Aug 62																					
1806	Jun 63	Dec 62																					
733	Jun 63	Aug 62	a		b		b		b	c													
732	Jun 63	Aug 62																					
904	Jun 63	Aug 62																					
1389	Jun 63	Oct 62	a		b		b		b		b	c											
1748	Jun 63	Dec 62																					
1750	Jun 63	Dec 62																					
1816	Jun 63	Dec 62	a		b		b		b		b		b	c									
1826	Jun 63	Dec 62																					
1778	Jun 63	Dec 62																					
1809	Jun 63	Dec 62	a		b		b		b		b		b		b	c							
1805	Jun 63	Dec 62																					
1815	Jun 63	Dec 62																					
1772	Jun 63	Dec 62			b		b		b		b		b		b		b	c					
1784	Jun 63	Dec 62																					
1804	Jun 63	Dec 62																					
587	Aug 66	Aug 62			b		b		b		b		b		b		b		b	c			
342	Jun 63	Dec 60																					
397	Jun 63	Dec 60																					
600	Aug 66	Aug 62			b		b		b		b		b		b		b		b		b	c	
639	Aug 66	Aug 62																					
682	Aug 66	Aug 62																					

*Test Sequence:
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing

Note: Ser No. 797 and 813 are held for backup.
Ser No. 209, 216, 387, and 189 have been replaced in the test schedule after the 48 mo test because electrical leads broke during vibration

**Zero time is manufacture date
***Initial time test

TABLE 2-5

FRANGIBLE SECTORS TEST SCHEDULE, WING I
(Storage Conditions: 100° F, 10 percent rh)

Sector Ser No.	Storage Date	Zero Time Date**	Test Sequence (mo from zero time)* 0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	114	120
645	Jun 63	May 62	a		c																	
1393	Jun 63	Oct 62	a		c																	
1534	Jun 63	Oct 62																				
648	Jun 63	May 62	a		b		c															
1531	Jun 63	Oct 62																				
1535	Jun 63	Oct 62																				
1792	Jun 63	Dec 62	a		b		b		c													
1752	Jun 63	Dec 62																				
1751	Jun 63	Dec 62																				
650	Jun 63	May 62	a		b		b		b		c											
655	Jun 63	May 62																				
683	Jun 63	May 62																				
688	Jun 63	May 62	a		b		b		b		b		c									
691	Jun 63	May 62																				
636	Jun 63	May 62																				
1553	Jun 63	Oct 62	a		b		b		b		b		b		c							
1547	Jun 63	Oct 62																				
1550	Jun 63	Oct 62																				
1764	Jun 63	Oct 62	a		b		b		b		b		b		b		c					
1551	Jun 63	Oct 62																				
1552	Jun 63	Oct 62																				
1390	Jun 63	Oct 62			b		b		b		b		b		b		b		c			
1756	Jun 63	Dec 62																				
1769	Jun 63	Dec 62																				
335	Jun 63	Dec 60			b		b		b		b		b		b		b		b		c	
393	Jun 63	Dec 60																				
413	Jun 63	Dec 60																				
401	Jun 63	Dec 60			b		b		b		b		b									
185	Jun 63	Dec 60																				
198	Jun 63	Dec 60																				

*Test Sequence:
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing

Note: Ser No. 335, 401, 185 and 198 have been deleted from the test schedule after the 60 mo test because electrical leads broke during vibration

**Zero time is manufacture date
***Initial time test

TABLE 2-6

FRANGIBLE SECTORS TEST SCHEDULE, WING I
(Storage Conditions: 70° F, 70 percent rh)

Sector Ser No.	Storage Date	Zero Time Date**	Test Sequence (mo from zero time)*																				
			0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
1760	Jun 63	Dec 62	a	c																			
1793	Jun 63	Dec 62																					
1795	Jun 63	Dec 62																					
1761	Jun 63	Dec 62	a		b	c																	
1794	Jun 63	Dec 62																					
1796	Jun 63	Dec 62																					
1763	Jun 63	Dec 62	a		b		b	c															
1798	Jun 63	Dec 62																					
1825	Jun 63	Dec 62																					
725	Jun 63	Aug 62	a		b		b		b	c													
717	Jun 63	Aug 62																					
773	Jun 63	Aug 62																					
1799	Jun 63	Dec 62	a		b		b		b		b	c											
1807	Jun 63	Dec 62																					
1767	Jun 63	Dec 62																					
1765	Jun 63	Dec 62	a		b		b		b		b		b	c									
1800	Jun 63	Dec 62																					
1808	Jun 63	Dec 62																					
1766	Jun 63	Dec 62	a		b		b		b		b		b		b	c							
1783	Jun 63	Dec 62																					
1802	Jun 63	Dec 62																					
1757	Jun 63	Dec 62			b		b		b		b		b		b		b	c					
1770	Jun 63	Dec 62																					
1777	Jun 63	Dec 62																					
396	Jun 63	Dec 60			b		b		b		b		b		b		b		b	c			
414	Jun 63	Dec 60																					
1392	Jun 63	Oct 62																					
694	Aug 66	Aug 62			b		b		b		b		b		b		b		b		b	c	
710	Aug 66	Aug 62																					
760	Aug 66	Aug 62																					

*Test Sequence:
- a = Transportation vibration (in accordance with qualification testing requirements)
- b = New transportation vibration and electrical check
- c = Operational vibration and destruct testing

Note: Ser No. 767 and 768 are held for backup.
Ser No. 187, 199, and 336 have been replaced in the test schedule after the 36 mo test because electrical leads broke during vibration

**Zero time is manufacture date
***Initial time test

TABLE 2-7

FRANGIBLE SECTORS TEST SCHEDULE, WING I
(Storage Conditions: 100° F, 70 percent rh)

Sector Ser No.	Storage Date	Zero Time Date**	Test Sequence (mo from zero time)* 0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
124 219 428	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60	a		c																		
155 221 430	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60	a		a		c																
1782 1785 1776	Jun 63 Jun 63 Jun 63	Dec 62 Dec 62 Dec 62	a		b		b		c														
577 690 762	Jun 63 Jun 63 Jun 63	Mar 62 May 62 Aug 62	a		b		b		b		c												
1753 1768 1780	Jun 63 Jun 63 Jun 63	Dec 62 Dec 62 Dec 62	a		b		b		b		b		c										
158 223 1790	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 62	a		b		b		b		b		b		c								
180 190 277	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60	a		b		b		b		b		b		b		c						
183 227 417	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60			b		b		b		b		b		b		b		c				
173 228 415	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60			b		b		b		b		b		b		b		b		c		
181 278 224	Jun 63 Jun 63 Jun 63	Dec 60 Dec 60 Dec 60			b		b		b		b		b		b		b		b		b		c

*Test Sequence:
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing
Note: Ser No. 158, 227, 181, and 224 have been deleted from the test schedule after the 60 mo test because electrical leads broke during vibration

**Zero time is manufacture date
***Initial time test

TABLE 2-8

FRANGIBLE SECTORS TEST SCHEDULE, WING II
(Storage Conditions at 70° F)

Sector Ser No. 10% rh	Storage Date	Zero Time Date**	Sector Ser No. 70% rh	Zero Time Date**	Test Sequence (mo from zero time)*																				
					0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
2027	Jun 63	Nov 62	1501	Nov 62	a	c																			
2111	Jun 63	Nov 62	1714	Nov 62																					
[illegible]	Jun 63	Nov 62	1746	Nov 62																					
[illegible]	Jun 63	Nov 62	1993	Nov 62																					
2112	Jun 63	Nov 62	1729	Nov 62	a		b	c																	
2119	Jun 63	Nov 62	1747	Nov 62																					
2267	Jun 63	Nov 62	1999	Nov 62																					
1340	Jun 63	Nov 62	2028	Nov 62																					
1258	Jun 63	Nov 62	1256	Nov 62	a		b		b	c															
1270	Jun 63	Nov 62	1266	Nov 62																					
1289	Jun 63	Nov 62	1288	Nov 62																					
1310	Jun 63	Nov 62	1308	Nov 62																					
1323	Jun 63	Nov 62	1319	Nov 62	a		b		b		b	c													
1336	Jun 63	Nov 62	1352	Nov 62																					
1353	Jun 63	Nov 62	1359	Nov 62																					
1358	Jun 63	Nov 62	1377	Nov 62																					
1364	Jun 63	Nov 62	1437	Nov 62	a		b		b		b		b	c											
1479	Jun 63	Nov 62	1487	Nov 62																					
1563	Jun 63	Nov 62	1730	Nov 62																					
1731	Jun 63	Nov 62	1748	Nov 62																					
1752	Jun 63	Nov 62	1784	Nov 62	a		b		b		b		b		b	c									
1789	Jun 63	Nov 62	2023	Nov 62																					
2031	Jun 63	Nov 62	2052	Nov 62																					
2060	Jun 63	Nov 62	2117	Nov 62																					
[illegible]	Jun 63	Nov 62	2142	Nov 62	a		b		b		b		b		b		b	c							
1274	Jun 63	Nov 62	1257	Nov 62																					
1290	Jun 63	Nov 62	1320	Nov 62																					
1311	Jun 63	Nov 62	1785	Nov 62																					
1293	Jun 63	Nov 62	1328	Nov 62			b		b		b		b		b		b		b	c					
1331	Jun 63	Nov 62	1355	Nov 62																					
1389	Jun 63	Nov 62	1373	Nov 62																					
1374	Jun 63	Nov 62	1388	Nov 62																					
1391	Jun 63	Nov 62	1278	Nov 62			b		b		b		b		b		b		b		b	c			
1294	Jun 63	Nov 62	1330	Nov 62																					
2039	Jun 63	Nov 62	1400	Nov 62																					
1390	Jun 63	Nov 62	2087	Nov 62			b		b		b		b		b		b		b		b		b	c	
1356	Jun 63	Nov 62	1778	Nov 62																					
1298	Jun 63	Nov 62	1850	Nov 62																					

*Test Sequence
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing

**Zero time is manufacture date
***Initial time test

TABLE 2-9

FRANGIBLE SECTORS TEST SCHEDULE, WING II
(Storage Conditions at 100° F)

Sector Ser No. 10% rh	Storage Date	Zero Time Date**	Sector Ser No. 70% rh	Zero Time Date**	Test Sequence (mo from zero time)*																				
					0***	9	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
1338	Jun 63	Nov 62	1251	Nov 62	a		c																		
1364	Jun 63	Nov 62	1260	Nov 62																					
1379	Jun 63	Nov 62	1281	Nov 62																					
1456	Jun 63	Nov 62	1300	Nov 62																					
1365	Jun 63	Nov 62	1252	Nov 62	a		b		c																
1380	Jun 63	Nov 62	1262	Nov 62																					
1470	Jun 63	Nov 62	1283	Nov 62																					
1505	Jun 63	Nov 62	1302	Nov 62																					
1254	Jun 63	Nov 62	1284	Nov 62	a		b		b		c														
1265	Jun 63	Nov 62	1305	Nov 62																					
1287	Jun 63	Nov 62	1350	Nov 62																					
1306	Jun 63	Nov 62	1366	Nov 62																					
1316	Jun 63	Nov 62	1383	Nov 62	a		b		b		b		c												
1337	Jun 63	Nov 62	1477	Nov 62																					
1360	Jun 63	Nov 62	1525	Nov 62																					
1378	Jun 63	Nov 62	1700	Nov 62																					
1449	Jun 63	Nov 62	1740	Nov 62	a		b		b		b		b		c										
1538	Jun 63	Nov 62	1783	Nov 62																					
1696	Jun 63	Nov 62	2003	Nov 62																					
1739	Jun 63	Nov 62	2110	Nov 62																					
1782	Jun 63	Nov 62	2126	Nov 62	a		b		b		b		b		b		c								
1991	Jun 63	Nov 62	2235	Nov 62																					
2030	Jun 63	Nov 62	1253	Nov 62																					
2048	Jun 63	Nov 62	1264	Nov 62																					
2107	Jun 63	Nov 62	1280	Nov 62	a		b		b		b		b		b		b		c						
2114	Jun 63	Nov 62	1299	Nov 62																					
2136	Jun 63	Nov 62	1317	Nov 62																					
2143	Jun 63	Nov 62	1361	Nov 62																					
1386	Jun 63	Nov 62	1324	Nov 62			b		b		b		b		b		b		b		c				
1618	Jun 63	Nov 62	1368	Nov 62																					
1736	Jun 63	Nov 62	1385	Nov 62																					
1763	Jun 63	Nov 62	1616	Nov 62																					
1277	Jun 63	Nov 62	1732	Nov 62			b		b		b		b		b		b		b		b		c		
1326	Jun 63	Nov 62	1753	Nov 62																					
1371	Jun 63	Nov 62	1803	Nov 62																					
1811	Jun 63	Nov 62	2061	Nov 62			b		b		b		b		b		b		b		b		b		c
2140	Jun 63	Nov 62	2139	Nov 62																					
2083	Jun 63	Nov 62	1276	Nov 62																					

*Test Sequence
a = Transportation vibration (in accordance with qualification testing requirements)
b = New transportation vibration and electrical check
c = Operational vibration and destruct testing

**Zero time is manufacture date

***Initial time test

3. Transportation Vibration

Transportation vibration of the frangible sector will be accomplished by mounting the sector assembly on the frangible sector vibration fixture, and vibrated as follows:

(a) Amplitude: 3.5 G rms between 5 to 50 cps; vibration limited to 0.4 in. peak-to-peak

(b) Range: 5 to 50 cps

(c) Duration: two double sweeps (5 to 50 cps and return to 5 cps for each double sweep) at 1/2 octave per minute in each of the three axes.

Note

All transportation vibration performed at zero time was in accordance with the qualification testing requirements as specified in Hercules Specification HPC-133-08-5-2A, Frangible Sector Assembly, paragraph 4.5.9. However this testing, when used during the testing sequences, would expose each frangible sector to vibration cycling in excess of that received by operationally deployed units. The vibration requirements shown above are considered a more realistic test.

4. Final Conditioning and Testing

a. Simulated Flight Vibration

The operational vibration for the frangible sector will consist of random vibration. The vibration axis shall be changed every 2 cycles. Flight altitude conditions will be simulated as follows:

(1) The frangible sector shall be installed in an enclosure simulating the TT port and mounted on the vibration table.

(2) Flight vibration conditions shall be simulated as specified in HPC-133-08-5-2, Frangible Sector Assembly, paragraph 4.5.11.

b. High Temperature Test

One Wing I and one Wing II frangible sector from each environment will be subjected to high-temperature testing to simulate flight heating. The units will be placed in a temperature chamber and subjected to a temperature of 250° F for a maximum of 10 min. They will then be inspected for

TABLE 2-16

FULL-SCALE UNIT CASE TEST SCHEDULE

Case No.	Applicable Wing No.	Storage Conditions		Zero Time Date*	Type Test Performed	Test Sequence (mo from zero time)**											
		Temp (^{o}F)	RH (%)			24	30	36	42	48	54	60	72	84	96	108	120
BB0156	I	80	50	Jan 63	LS & SBS***			b		b		b		b			
BB0164	I	80	50	Jan 63	LS & SBS			b			b		b		b		
BB0180	I	80	50	Feb 63	LS & SBS			b				b			b		b
BB0152	I	80	50	Dec 62	Hydroburst	a											
BB0162	I	80	50	Jan 63	Hydroburst LS & SBS			ab									
R206X.13	I	80	50	Feb 62	Hydroburst LS & SBS					ab							
R205X.62	I	80	50	Jan 62	Hydroburst LS & SBS							ab					
R205X.20	I	80	50	Jan 62	Hydroburst LS & SBS								ab				
R205X.18	I	80	50	Jan 62	Hydroburst LS & SBS						ab						
HP00253	II	80	50	Jan 64	LS & SBS	c	c	c	c	c	c	c	c				
HP00026	II	80	50	Feb 63	LS & SBS		c	c	c	c	c	c	c	c			
P120Y.03	II	72	Amb	Oct 62	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
P120Y.04	II	72	Amb	Oct 62	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0170	I	72	Amb	Jan 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0172	I	72	Amb	Jan 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0175	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										

*,**,*** See end of table for legend

TABLE 2-16 (Cont)

FULL-SCALE UNIT CASE TEST SCHEDULE

Case No.	Applicable Wing No.	Storage Conditions Temp (°F)	Storage Conditions RH (%)	Zero Time Date*	Type Test Performed	Test Sequence (mo from zero time)** 24	30	36	42	48	54	60	72	84	96	108	120
BB0176	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
BB0181	I	72	Amb	Feb 63	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
T402.35	PFRT	72	Amb	Nov 60	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										
Q206.60	PFRT	72	Amb	Nov 61	Hydroburst LS & SBS		Backup cases, not presently scheduled for testing										

*Zero time date is date of fabrication

**Test Sequence:
- a - Hydroburst
- b - Cut, machine, and test LS & SBS specimens (8 ea)
- c - Cut, machine, and test LS & SBS specimens (4 ea)

***LS - Lap shear cut from cases

***SBS - Short beam shear cut from cases

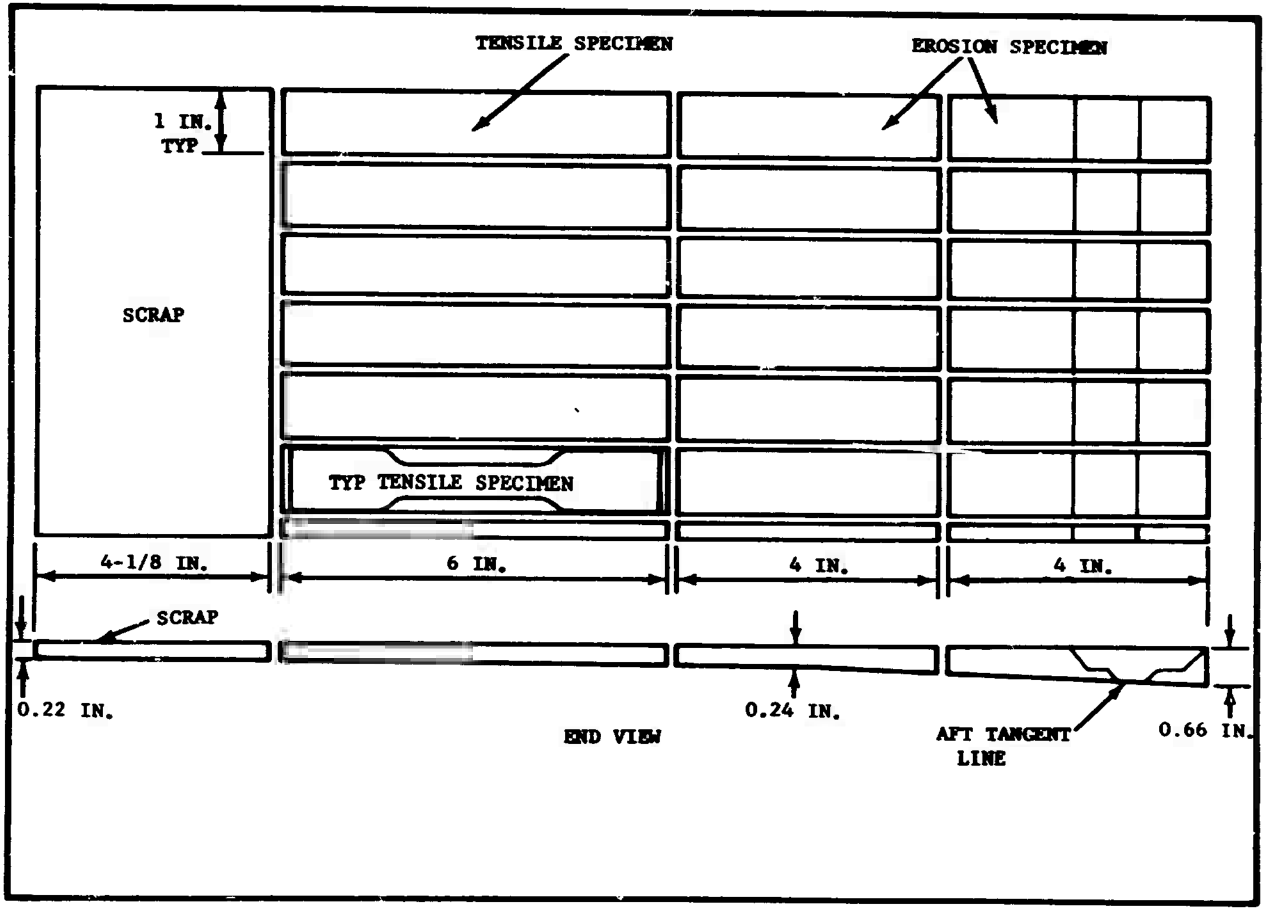


Figure 2-23. Typical Internal Insulator Sample Section

TABLE 2-25

FULL-SCALE UNIT RUBBER SAMPLES TEST SCHEDULE

Grain No.	Wing No.	Zero Time Date*	Section No.	Type Test	Test Sequence (mo from zero time) 30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
336	II	Dec 62	1-1	Tensile	6**															
336	II	Dec 62	1-1	Erosion	12															
336	II	Dec 62	1-2	Tensile			6													
336	II	Dec 62	1-2	Erosion			12													
336	II	Dec 62	1-3	Tensile					6											
336	II	Dec 62	1-3	Erosion					12											
336	II	Dec 62	1-4	Tensile							6									
336	II	Dec 62	1-4	Erosion							12									
336	II	Dec 62	1-5	Tensile									6							
336	II	Dec 62	1-5	Erosion									12							
336	II	Dec 62	1-6	Tensile											6					
336	II	Dec 62	1-6	Erosion											12					
336	II	Dec 62	1-7	Tensile													6			
336	II	Dec 62	1-7	Erosion													12			
336	II	Dec 62	1-8	Tensile															6	
336	II	Dec 62	1-8	Erosion															12	
1M1	I	Dec 62	1-1	Tensile	6															
1M1	I	Dec 62	1-1	Erosion	12															
1M1	I	Dec 62	1-2	Tensile		6														
1M1	I	Dec 62	1-2	Erosion		12														
1M1	I	Dec 62	1-3	Tensile			6													
1M1	I	Dec 62	1-3	Erosion			12													
1M1	I	Dec 62	1-4	Tensile				6												
1M1	I	Dec 62	1-4	Erosion				12												
1M1	I	Dec 62	1-5	Tensile					6											
1M1	I	Dec 62	1-5	Erosion					12											
1M1	I	Dec 62	1-6	Tensile													6			
1M1	I	Dec 62	1-6	Erosion													12			
1M1	I	Dec 62	1-7	Tensile														6		
1M1	I	Dec 62	1-7	Erosion														12		
1M1	I	Dec 62	1-8	Tensile																6
1M1	I	Dec 62	1-8	Erosion																12
131	I	Jan 61	1-1	Tensile					6											
131	I	Jan 61	1-1	Erosion					12											
131	I	Jan 61	1-2	Tensile						6										
131	I	Jan 61	1-2	Erosion						12										
131	I	Jan 61	1-3	Tensile							6									
131	I	Jan 61	1-3	Erosion							12									
131	I	Jan 61	1-4	Tensile								6								
131	I	Jan 61	1-4	Erosion								12								
131	I	Jan 61	1-5	Tensile									6							
131	I	Jan 61	1-5	Erosion									12							
131	I	Jan 61	1-6	Tensile										6						
131	I	Jan 61	1-6	Erosion										12						
131	I	Jan 61	1-7	Tensile											6					
131	I	Jan 61	1-7	Erosion											12					
131	I	Jan 61	1-8	Tensile												6				
131	I	Jan 61	1-8	Erosion												12				

*Zero time date is cast date of motor

**Numbers indicate specimens tested

2. Storage

a. Nozzle Pivot Sections

The nozzle pivot sections will be stored at 60°, 80°, and 100° F. The relative humidity of the 60° and 100° F buildings is ambient. The 80° F building is controlled at 50 percent relative humidity.

b. (Paragraph deleted)

3. Testing

a. Nozzle Pivot Sections

1) Fixture Cycling

To perform the actuating torque test and the O-ring pressure seal test, fixtures were designed (drawing No. 1264-BU) which simulate the nozzle pivot section. Figure 2-28 is a photograph of the fixture components. Each fixture will contain two O-rings throughout storage and testing to duplicate the conditions encountered in the third stage nozzle during silo storage.

The failure criteria employed in this study are actuating torque and the ability of the O-rings to maintain a seal against a pressure of 200 psig.

One of the two O-ring test fixtures of each system at each storage temperature will be used as a control, while the other will be cycled 4° right to 4° left at 60 cpm for 1 min per test period. Figure 2-29 shows the fixture cycling apparatus.

2) Pressure Application

A pressure dome is bolted to the fixture (Figure 2-30), and as in the pressure leak test on the nozzle assembly, a pressure of 200 psi is introduced into the fixture and held for 1 min. A drop-in pressure, which can be observed on the pressure gage, indicates a leak past the O-rings. In the event of a leak, the fixture will be disassembled, the O-rings removed, and an examination of the O-rings made to discover the cause of the leak. This test is performed in accordance with Operating Instruction (OI) 7-7.15.2.

b. Breakaway Torque Test

The Inscron Tester measures and records the torque required to vector the O-ring fixture. (See Figure 2-31.) O-ring breakaway will be tested according to Bacchus Laboratory Procedure, Section II, Method 22.

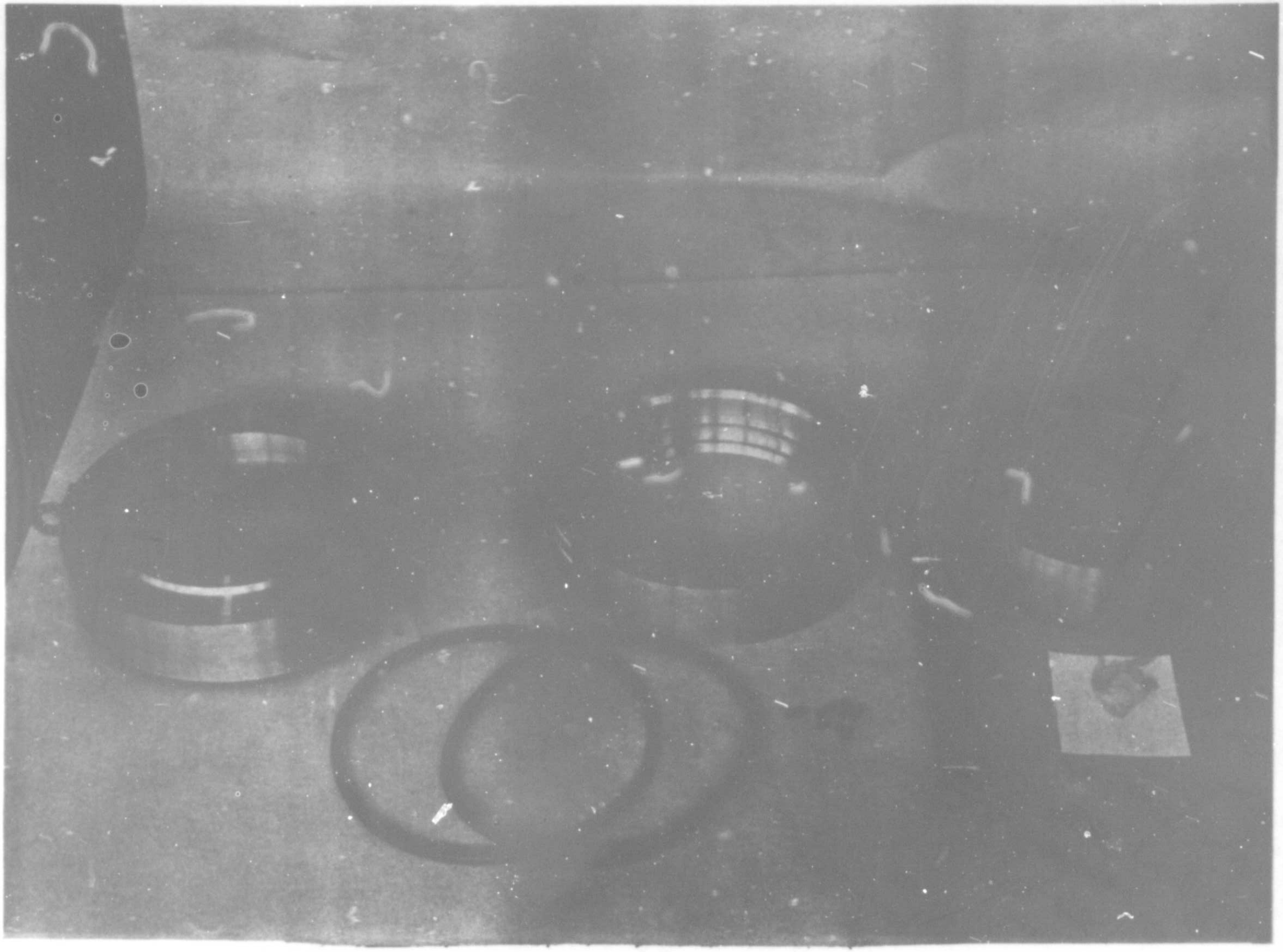


Figure 2-28. Component Parts of the O-Ring Test Fixture

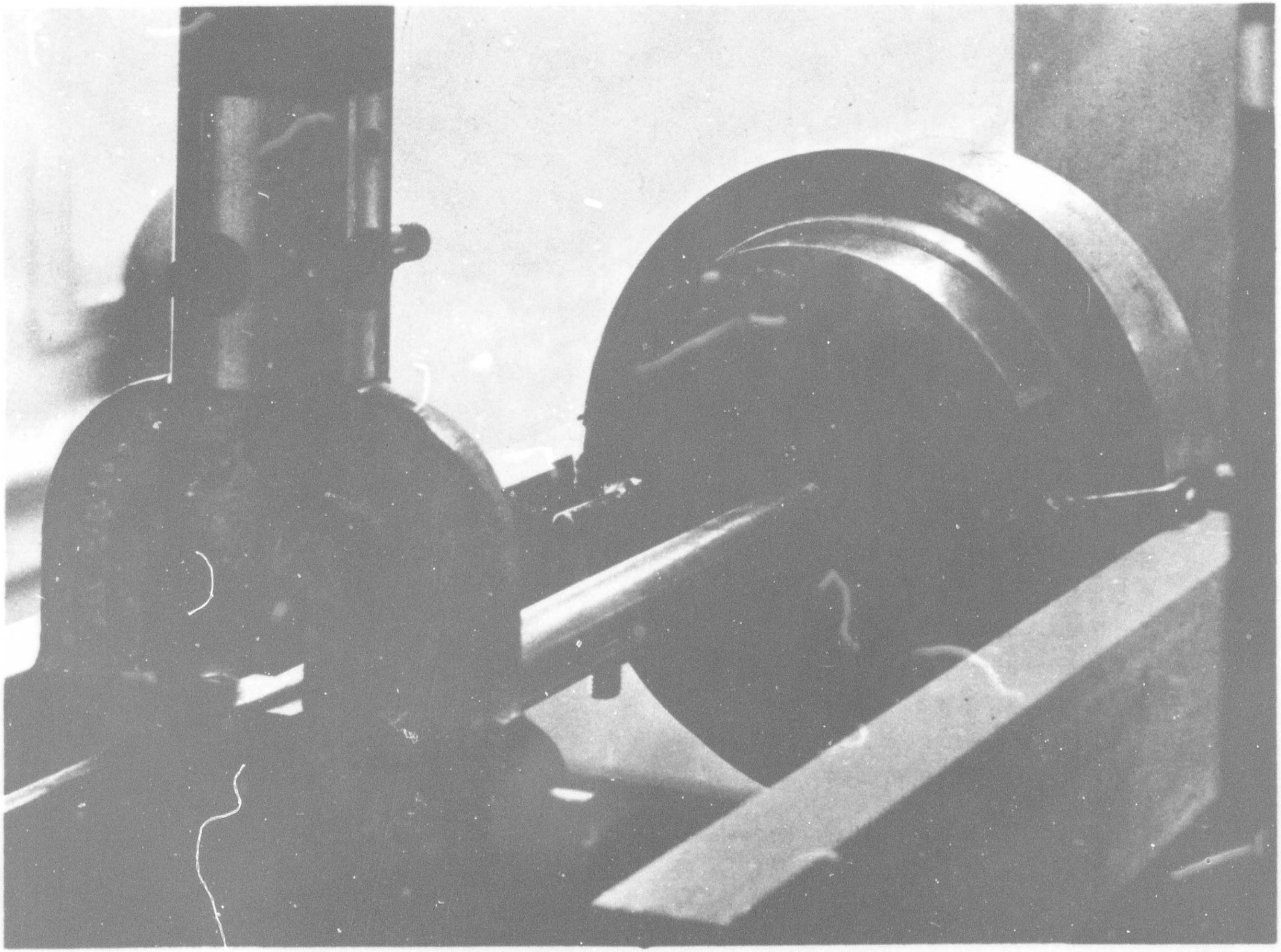


Figure 2-31. Fixture Mounted and Ready for Testing on the Instron

(Sentence deleted)

C. DATA EVALUATION

Service life prediction of the O-rings in the nozzle and nozzle port area has been based on an extrapolation of the regression analysis of hardness and elongation data; however, the physical testing of O-rings is complete with the 30-mo testing. The service life value based on this data is 6 yr.

In the future, the service life value will be based on the nozzle ball-joint breakaway torque and pressure seal ability data. The service life prediction has been extended to 10 yr based on this data.

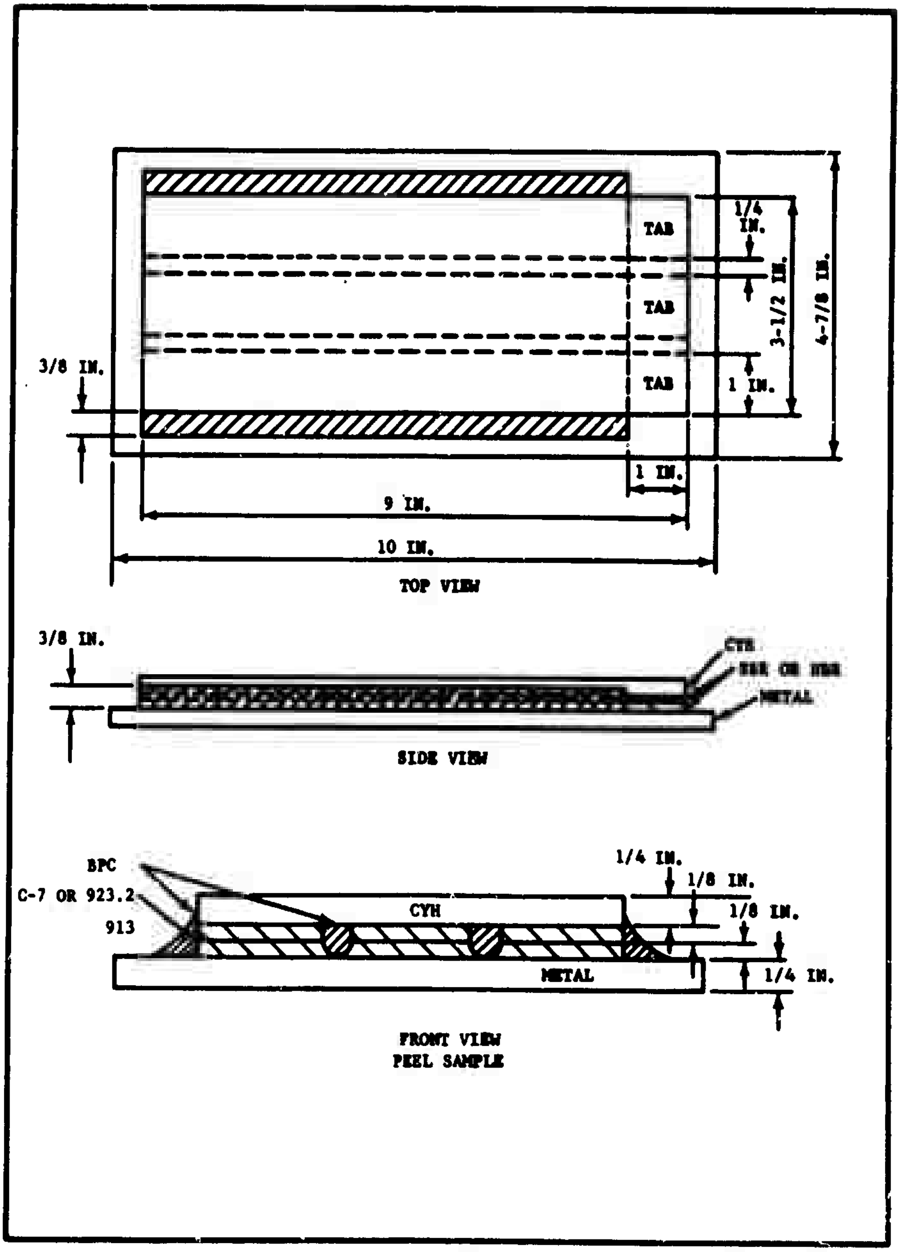


Figure 2-34. Peel Sample

g. Compatibility Specimens

Potting compound will be placed in direct contact with propellant (sandwiches), as shown in Figure 2-35, and exposed to propellant vapors, as shown in Figure 2-36. Samples will be prepared for each potting compound-CS, BPC, and polyurethane.

2. Storage

All samples will be placed in the storage conditions indicated in Table 2-35 at 60° F, 80° F, or 100° F.

3. Testing

a. Physical Tests

The B-1 Fix specimens will be removed according to Table 2-35, visually inspected, photographed, and transportation vibrated when applicable. Transportation vibration will consist of the following:

(1) Amplitude, 3.5g rms between 5 and 50 cps; vibration limited to 0.4 in. peak-to-peak

(2) Range, 5 to 50 cps

(3) Duration, two double sweeps (5 to 50 cps and return to 5 cps for each double sweep) at 1/2 octave per min in two axes.

Any variations noted in any specimen from previous visual inspections and photographs will be recorded and reported in the status report.

The following specimens will be withdrawn from storage according to Table 2-35 and conditioned and tested at the Bacchus chemical laboratory according to the procedures listed:

Samples	Test	Laboratory Procedure Method
Tensile	Tensile test	Section III, Method 61
Tensile	Percent elongation	Section III, Method 61
Tensile	Hardness (Shore A)	Section III, Method 21
Lap shear	Shear test	Section III, Method 16
Peel	Peel test	Section III, Method 29

(b) Resin

(1) Characterization of each barrel of resin to be used by gas chromatography techniques

(2) Characterization of each barrel of resin to be used by refractive index techniques

(3) Periodic check of the resin stored in barrels for moisture content

(c) Hardener

(1) Characterization of each barrel of hardener by refractive index technique

(2) Periodic check of moisture content of each barrel of hardener

(d) Resin/Hardener Mixture

(1) Check by RI techniques and correction, if necessary, of the mix ratios for each mix used in winding cylinders or vessels

2. <u>Test Development and Shear Strength Determination</u>

New token shear test specimens and test methods (for both axial and bending-type loading) will be developed to determine actual interlaminar shear (ILS) capability for filament-wound, helical-to-helical interfaces (layer lap shear, Type 1): helical-to-mat-wind interfaces (layer lap shear, Type II): and helical-to-spiral-wound, B-staged, port-reinforcement-wafer interfaces (wafer lap shear, Type I and II). Using these tests, ILS strength values will be established for the various types of interfaces for both bending and axial type loading. Correlation of results of bending tests for various types of interfaces with results which have previously been obtained from short beam shear testing will be studied. Also, correlations evident between material properties, resin content, void content, wafer B-stage condition, etc, with shear capability for the various types of interfaces will be established.

The layer and lap shear specimens are shown in Figures 2-9 and 2-10. The general scheme for obtaining these specimens from the Spiralloy cylinders is also illustrated. The winding geometry of the cylinders will be varied in order to find the most representative failure mode. The specimens will be tested as shown in Figure 2-14. A sleeve will be positioned around the shear area to prevent nonaxial loading.

Short-beam-shear type (bending shear) specimens, as shown in Figure 2-55, will also be cut from the cylinders and loaded as shown in Figure 2-55A for bending shear considerations.

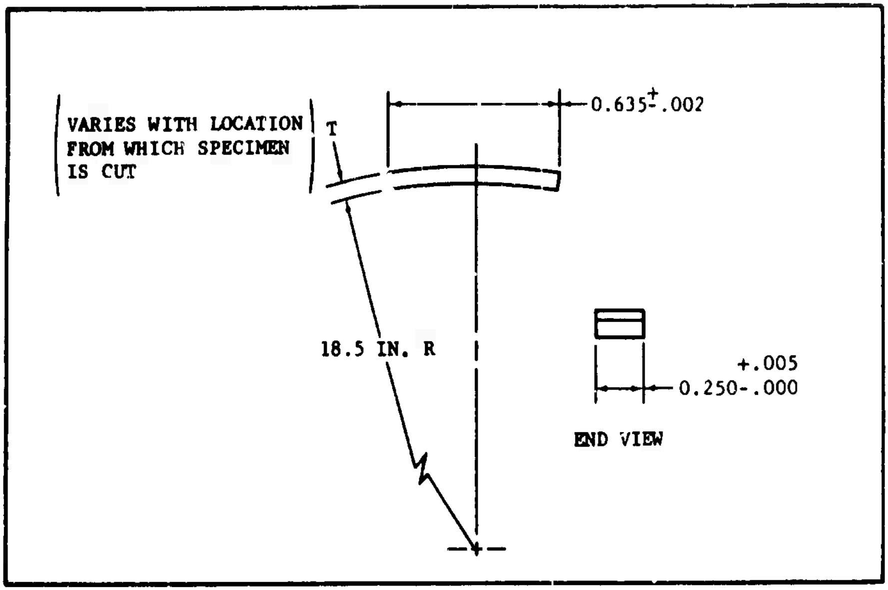


Figure 2-55. Typical Short Beam Shear Specimen

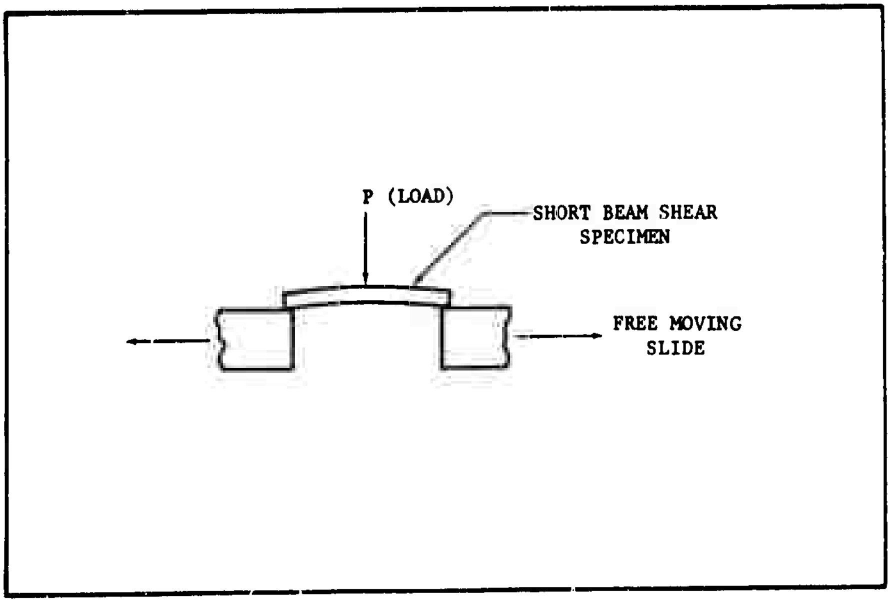


Figure 2-55A. Typical Short Beam Shear Loading Diagram

The various types of specimens will be analyzed by photomicrograph techniques to determine the details of specimen structure (filament/resin distribution, void regions, etc) after cure. The various types of short beam shear specimens will also be analyzed after failure by photomicrograph techniques to determine at which interface the failure actually occurred.

The percentage by weight of resin content and void content will also be determined for each type of shear specimens.

Three cylinders, as shown in Figure 2-9, will be wound. A total of 125 specimens will be obtained from this type of cylinder.

Six cylinders, as shown in Figure 2-10, will be wound. A total of 100 Type I wafer-shear tests, 100 Type II layer-lap-shear specimens, 25 short-beam-shear specimens from the wafer area, and 25 short-beam-shear specimens from the helical area will be obtained from this type of cylinder.

Four cylinders, as shown in Figure 2-10 will be wound. A total of 60 type II wafer-shear specimens and 25 short-beam-shear specimens will be obtained from this type cylinder.

These cylinders will be wound at the Hercules' Clearfield, Utah, winding facility. Complete records of winding techniques used and details of winding will be kept.

3. Subscale Dome-to-Dome Wafer Vessel Analysis and Testing

A total of 24 dome-to-dome wafer vessels per drawing 12500524 will be wound. The winding geometry for these vessels consists of a pole-piece, centered in a 10-in.-dia wafer, sandwiched between two helical-wound layers. These vessels will be wound at the Hercules' Clearfield winding facility. Complete records of winding techniques used and wi ding details will be kept. High-speed movies will be taken during six of the burst tests to define the area of failure initiation. Percentage by weight of resin content and void content will be determined for each vessel. Photomicrographs of vessel cross sections will also be made to determine the details of the material structure.

4. Minuteman Wing II Full-Scale-Unit Analysis and Testing

A total of 50 specimens with a configuration similar to Type I layer-lap-shear specimens and 25 short-beam-shear-type specimens will be obtained from the cylindrical section of Wing II Minuteman hydroburst cases and tested. Each type of specimen will be characterized by photomicrograph techniques, and percentage by weight of resin and void content will be determined. Also 25 short-beam-shear-type specimens will be obtained from the domes of Minuteman Wing II cases. These specimens will also be characterized by photomicrographs, and percentage by weight of resin content and void content will be determined.

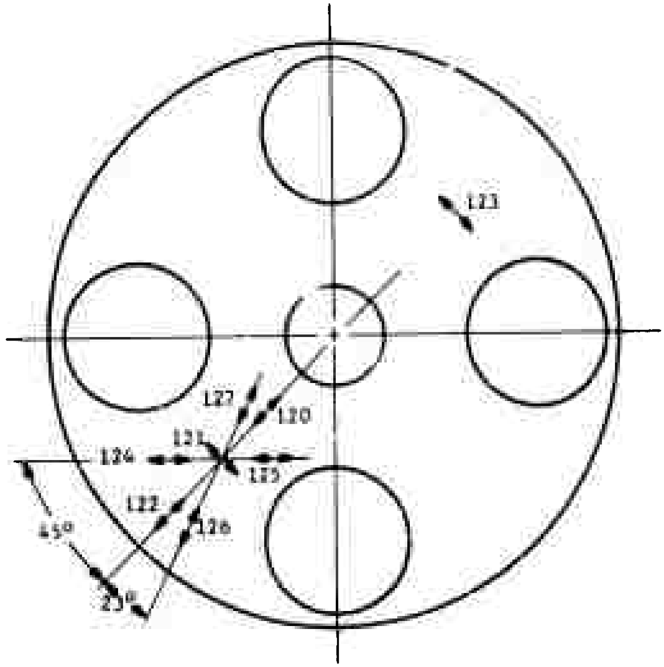
5. Full-Scale Hydroburst Instrumentation

Flexagages will be located on the aft dome of up to 18 Minuteman QA hydroburst FSU cases as shown in Figure 2-55B. The data from these gages will be used to determine axial and bending strains in the area where the majority of FSU cases ultimately fail. The strains will then be used in orthotropic equations with orthotropic elastic properties to calculate maximum fiber stresses in the various dome layers. These stresses will then be converted to load per inch which must be transferred from fibers into wafers by shear. Shear stresses will then be calculated and compared with applicable lap-shear results to establish a shear failure criteria for the case.

D. MILESTONE

The following schedule is provided as a completion schedule. All effort to be complete by 1 October 1966.

TASK	1965								1966								
SPIRALLOY	7 M	8 J	9 J	10 A	11 S	12 O	13 N	14 D	15 J	16 F	17 M	18 A	19 M	20 J	21 J	22 A	23 S
FABRICATE SAMPLES		△									▲						
TEST - SHEAR SPECIMENS				△									▲				
- WATER BOTTLES						△				▲							
ANALYZE DATA	△														▲		
FABRICATE STORAGE SAMPLES								△					▲				



HORIZONTAL PROJECTION
FROM CASE CENTER LINE

GAGE NO.	DIRECTION	LOCATION
F 120	MERIDIAN	9.0°
F 121	HOOP	10.5°
F 122	MERIDIAN	12.5°
F 123	HOOP	10.5°
F 124	45°	13.5°
F 125	45°	8.5°
F 126	23°	13.5°
F 127	23°	8.5°

Figure 2-55B. Flexagage Location for FSU Case Pressure Cycle Test

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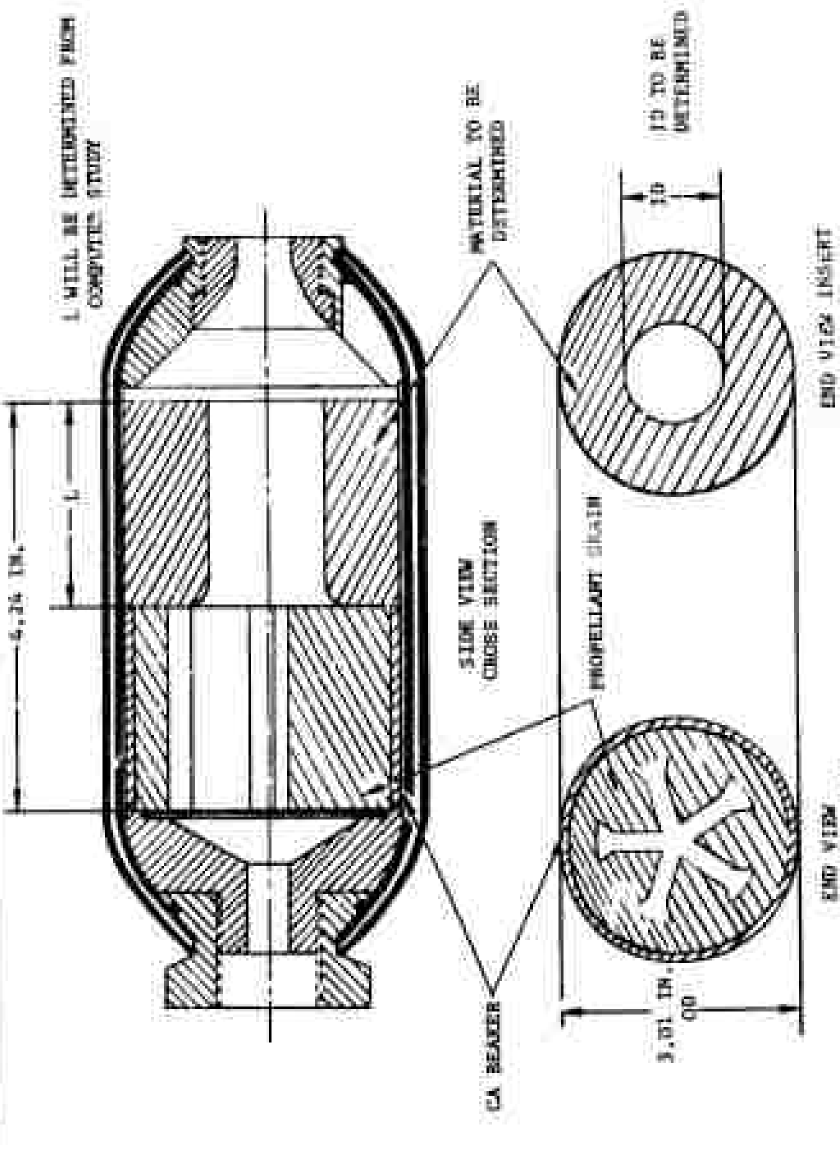

Figure 2-56. Detailed View of Inhibited Igniter

TABLE 2-42

IGNITER ACCELERATED AGING
TEST SCHEDULE

Igniter Test No.*	Zero Time**	Storage Temp (°F)	Test Sequence (mo)*** 0	3	6	12	18
1	Dec 1966	amb	ab				
2		120		ac			
3		120		ac			
4		120		ab			
5		120			ac		
6		120			ac		
7		120			ab		
8		120				ac	
9		120				ac	
10		120				ab	
11		120					ac
12		120					ac
13	Dec 1966	120					ab

* Igniter S/N to be added upon receipt of igniters
** Zero Time is expected receiving date
*** Test Sequence:
a = Radiographic inspection
b = Gas sample and dissection followed by:
(1) Visual and dimensional inspection
(2) Profile study (three samples)
(3) Ignitability study (six specimens)
(4) Heat-of-reaction of pellets (six specimens)
(5) Strand burning rate study (six specimens)
(6) Heat of explosion of propellant (six specimens)
c = Static test at simulated altitude conditions

Technical Operating Report
B O B Approval No. ______

MOTOR STORAGE STUDIES PROGRAM PLAN

MTO-258-3A, REVISION 2

WEAPON SYSTEMS 133A AND B

15 January 1966
Changed 1 September 1966

Volume II

Contract Number AF 04(694)-544

LATEST CHANGED PAGES SUPERSEDE
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HERCULES INCORPORATED
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
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LIST OF EFFECTIVE PAGES (Volume II) 1 September 1966

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Page No.	Issue
*Title	1 Sep 66
*A	1 Sep 66
*i	1 Sep 66
ii thru vi	1 Jul 66
*vii	1 Sep 66
3-1 thru 3-29	Original
*3-30	1 Sep 66
3-31	Original
3-32	1 Jul 66
3-33 and 3-34	Original
*3-35	1 Sep 66
3-36	Original
3-37	1 Jul 66
*3-38	1 Sep 66
3-39	1 Jul 66
*3-40	1 Sep 66
3-41 Added	1 Jul 66
3-42 Blank	1 Jul 66
A-1	Original
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*A-4A and A-4B Added	1 Sep 66
A-5 thru A-7	Original
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A-9 thru A-17	Original
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A-19 thru A-21	Original
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A-23 thru A-37	Original
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B-1	1 Jul 66
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C-1 thru C-7	Original
C-8 Blank	Original
D-1 thru D-4	Original

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MOTOR STORAGE STUDIES PROGRAM PLAN
WEAPON SYSTEMS 133 A and B

Volume II

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FOREWORD

This document presents the Motor Storage Studies Program Plan and the Hercules plan for development of failure criteria.

The original authority and requirements for motor storage studies were established in Contract AF 04(647)-243, Exhibit B, paragraph III.F.5, and Exhibit D, Section III, paragraph D.9; and as amended by CCN's No. 108, 165, and 200.

Authority for continuation of the motor storage program from 1 July 1963 thru 30 June 1965 is given in Contract AF 04(694)-127, Exhibit A, paragraph D.9, as amended by CCN No. 50.

This document supersedes MTO-258-3A, Revision 1, Motor Storage Studies Program Plan, dated 1 December 1964, and is presented in two volumes. Volume I contains the effort which was transferred from Air Force Systems Command (AFSC) to Air Force Logistics Command (AFLC) in the transfer of engineering responsibility of Wing I thru Wing V. Each test schedule indicates the effort remaining as of transfer date, 1 October 1966.

Volume II contains the effort for full-scale units and materials unique to Operational Reliability Improvement (OPRI), which is the responsibility of AFSC.

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HERCULES INCORPORATED
Bacchus Works
Magna, Utah

LIST OF TABLES

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TABLE 3-6

NOZZLE MOVEMENT SCHEDULE, WING II AND WING IV

Time (sec)	Pitch Nozzles	Yaw Nozzles	Roll Nozzles
0 to 5	$\pm 4^\circ$ at 0.5 cps	$\pm 4^\circ$ at 0.5 cps in phase with pitch motion	None
5 to 10	$\pm 2^\circ$ at 1 cps	$\pm 2^\circ$ at 1 cps in phase with pitch motion	None
10 to 15	Fixed at $\pm 2^\circ$	Fixed at 0°	None
15 to 20	Fixed at 0°	Fixed at 2°	None
20 to 25	$\pm 2^\circ$ at 0.5 cps	$\pm 2^\circ$ at 0.5 cps in phase with pitch motion	None
25 to 30	$\pm 2^\circ$ at 0.5 cps	No yaw vector	Nozzle No. 3, $\pm 2^\circ$ at 0.5 cps in phase with pitch motion. Nozzle No. 1, fixed at 0°
30 to 35	$\pm 1^\circ$ at 2 cps	$\pm 1^\circ$ at 2 cps in phase with pitch motion	None
35 to 40	Fixed at -1°	Fixed at -1°	None
40 to 45	$\pm 2^\circ$ at 0.5 cps	$\pm 2^\circ$ at 0.5 cps in phase with pitch motion	None
45 to t_a	$\pm 1^\circ$ at 1 cps	$\pm 1^\circ$ at 1 cps in phase with pitch motion	None

Notes:

(1) The above movement schedule is an input schedule from the programmer
(2) $\pm$ indicates sinusoidal motion
(3) In TT tests, the movable nozzles shall be in a neutral position at the time of TT
(4) When a phase III NCU is used, there will not be a roll command Nozzle 3 command will be the same as nozzle 1 command
(5) t_a is when the thrust descends to 750 lb

J. DATA EVALUATION

1. Evaluation of Motor Inspection Data Preliminary to Static Firing

The data obtained from the periodic motor inspections during storage at HAFB will be evaluated for each motor prior to static firing. The purpose of the evaluation is to determine the areas which have shown degradation and may require monitoring during static firing.

2. Comparison and Evaluation of Firing Data

Data developed from the Wing I motor static firing will be compared to PFRT data, and Wing II and Wing IV motor static firing data will be compared to data recorded on Wing II and Wing IV qualification motors to determine degradation of the measurement parameters and to establish the reliability of the aged motor. In all cases, the comparison will include evaluation of motor performance with model specifications and predicted values. Components of design different from PFRT will be evaluated separately, using data obtained from motors of a similar configuration. If failure occurs during static firing, the evaluation will proceed.

3. Data Reduction

Data from storage motor firings will be reduced in accordance with Hercules report MTO-25-3, Section VIII.

4. Reporting

As required in STL Document GM 61-9734.2-1045, Revision 1, Hercules will prepare an Individual Motor Final Test Report on each motor. This report will include:

(a) Summary of test handling and inspection operations

(b) Review of test objectives

(c) Description of test events and predicted and measured system performance

(d) Posttest inspection data

(e) Detailed conclusions

(f) Reliability classification of subsystems as success or failure

(g) Detailed recommendations

5. Documentation

Hercules will issue a final firing report 45 days after each firing. The report will contain a detailed analysis of the firing and will incorporate and summarize essential data from other test firings. This data will include predicted values for motor performance, test objectives, etc. The predicted performance values will include tabulated pressure-time data and other parameters given in the motor acceptance log book.

TABLE 3-9

CASE-BOND TEST SCHEDULE

System No.	Test Performed	Storage Temp (°F)	Zero Time Date*	Test Sequence (mo from zero time) 0	3	6	9	12	15	18	21	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
15	Tensile	60	Jul 62	8**						8		8			8													
		100	Jul 62	8	8	8	8	8	8	8	8	8	8	8		8 specimens held for backup												
17	Tensile	100	May 63	8	8	8	8	8		8						72 specimens held for backup												
18	Tensile	100	May 63	8	8	8	8	8		8						72 specimens held for backup												
19	Tensile & Chemical	60	Aug 64						8	8	8	8	8	8	8	8	8	8	8									
		100	Aug 64						8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
21	Peel	60	Mar 66	3		63 specimens held for backup																						
		100	Mar 66	3	72 specimens held for backup																							
22	Peel & Chemical	60	Mar 66	3		3		3		3		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		100	Mar 66	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

*Zero time is fabrication date

**Number of specimens tested

c. Peel Strength

The 90° peel test will be conducted in accordance with Bacchus Laboratory Procedure, Section III, Method 57. The peel specimens will be tested in accordance with the schedule in Table 3-9.

The Case Bond Failure Criteria Study presented in Chapter 2, Section XIV should provide the required test improvements and corresponding failure criteria.

Until the improved tests and failure criteria can be obtained, the evaluation of case-bond data will be limited to the present trend analysis to verify that degradation does not occur.

SECTION III

OPERATIONAL RELIABILITY IMPROVEMENT, ADHESIVE AND POTTING COMPOUND SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

This study includes the following types of adhesive in combination with potting compounds and propellant to be studied as candidate materials for Wing VI: (1) Adhesive conforming to specification HPC-133-08-7-56, Type III (948.2/953), used to bond boot to flap; (2) rubber cement conforming to specification HPC-133-08-10-14 (SBR/Skellysolve-B), used to bond boot to flap prior to vulcanizing; and (3) adhesive conforming to specification HPC-133-08-7-31, composition (Epon 923.2) used as case-bond powder embedment bonding agent.

Potting compound BPC No. 2 will be used around the nozzle-to-propellant interface.

B. DETAILED TEST PLAN

The types of specimens to be used and the quantity of each are as contained in Table 3-10. Specimen configuration was chosen to simulate suspected modes of failure for each adhesive being studied. Testing will be conducted as indicated in Tables 3-11 and 3-12.

1. <u>Preparation of Specimens</u>

a. <u>Boot-to-Flap Peel</u>

Metal plates will be cut to 10- x 5- x 1/2-in. size, and rubber sections will be cut to 6- x 4-in. size prior to vulcanizing. Rubber sections will be cut to 6 x 3-1/4 in. size following the vulcanizing sequence. Following the bonding of these components, a 1/4-in.-wide groove will be cut in the rubber sections, leaving three 1-in.-wide rubber strips on each plate. (Samples will have the same basic configuration as shown in Figure 2-34 with the following modifications: Rubber strips will be 1- x 6-in. size, no potting compound will be used, and propellant sections will be eliminated.) The procedure is as follows:

(1) Rubber is cut to 4- x 6-in. sections.

(2) The 4- x 6-in. boot and flap rubber sections are sanded.

(3) One boot and one flap-type rubber section are vulcanized together leaving a 1-in. flap along one 4-in. side. (Teflon tape is used as a barrier for the 1-in. flap section.)

(4) Metal plates are sand blasted and degreased.

TABLE 3-10

ADHESIVE AND POTTING COMPOUND
MATERIALS AND TEST DESCRIPTION

Material	Type of Test	Type of Sample*	Original Quantity
Epon 948.2/953	Tensile	JANAF	96
	Lap shear	Al/Al	96
	Lap shear	Al/SBR/Al - BPC-2/CYH	264
	Peel	SBR/SBR - BPC-2/CYH	264
Epon 923.2	Lap shear	Al/NBR/Al - BPC-1/CYH	120
	Lap shear	Al/SBR/Al - BPC-1/CYH	120
	Peel	NBR/NBR - BPC-1/CYH	120
	Peel	SBR/SBR - BPC-1/CYH	120
BPC-2	Chemical analysis and compatibility	Compatibility and B-1 fix configuration	8

*Type of Sample - JANAF (See Figure 2-32), Lap Shear (See Figure 2-32), Peel (See Figure 2-34), Compatibility (See Figures 2-35 and 2-36), B-1 Fix (See Figure 2-33)

Al - Aluminum, NBR - Buna-N Rubber, SBR - Buna-S Rubber, BPC - Bacchus Potting Compound, CYH - Propellant

TABLE 3-11

POTTING COMPOUND TEST SCHEDULE

Material	Fabrication Date	Store Temp (°F)	Test Sequence (mo from zero time)*										
			0	6	12	18	24	30	36	42	48	54	60
B-1 fix	Nov 65	100	a	a	a	a	a	a	a	a	a	a	a
	Nov 65	100	a	b	b	b	b	b	b	b	b	b	b
Bacchus potting compound No. 2	Nov 65	60	a	a	a	a	a	a	a	a	a	a	a
	Nov 65	60	a	b	b	b	b	b	b	b	b	b	b

*Test Sequence:

a = Inspect and photograph

b = Remove from storage, inspect, vibrate, and photograph

TABLE 3-12

ADHESIVE COMPOUND TEST SCHEDULE

Materials[a]	Test	Zero Time Date[b]	Store Temp (°F)	Test Sequence (mo from zero time)															
				0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
Epon 948.2/953	Tensile[c]	Mar 66	100	4[d]	4	4	4	4	4	4	4	4	4	4					
	Tensile	Mar 66	80	4		4		4		4		4		4	4	4	4	4	4
Epon 948.2/953	Lap shear	Mar 66	100	4	4	4	4	4	4	4	4	4	4	4					
			80	4		4		4		4		4		4	4	4	4	4	4
Epon 948.2/SRB																			
(Plain)	Lap shear	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(Plain)	Lap shear	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(BPC No. 2)	Lap shear	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(BPC No. 2)	Lap shear	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(Plain)	Peel	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(Plain)	Peel	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(BPC No. 2)	Peel	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(BPC No. 2)	Peel	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
Boot-to-flap	Peel	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
	Peel	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6

[a] Material: SRB - Buna-S Rubber, BPC - Bacchus Potting Compound

[b] Zero time date is fabrication date

[c] Tensile specimens are tested for tensile, elongation, and hardness

[d] Numbers of specimens tested

TABLE 3-12 (Cont)

ADHESIVE COMPOUND TEST SCHEDULE

Materials[a]	Test	Zero Time Date[b]	Store Temp (°F)	Test Sequence (mo from zero time) 0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
Epon																			
923.2/NBR	Lap Shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/NBR	Lap shear	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
923.2/NBR	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/NBR	Peel	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
Epon																			
923.2/SBR	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/SBR	Lap shear	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
923.2/SBR	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/SBR	Peel	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
BPC-2	Chemical	Nov 65	100	1	1	1	1	1	1	1	1	1	1	1					
			60	1	1	1	1	1	1	1	1	1	1	1					

(a) Material: SBR - Buna-S Rubber, PPC - Bacchus Potting Compound

(b) Zero time date is fabrication date

(c) Tensile specimens are tested for tensile, elongation, and hardness

(d) Numbers of specimens tested

APPENDIX A

COMPLETED OR DISCONTINUED TEST PLANS

SECTION I

PROPELLANT TEST PLAN

A. INTRODUCTION

1. Part Description

The propellant samples described in this test plan are CYH and DDP formulations that differ slightly from the stage III propellants. The present stage III CYH and DDP propellant formulations are manufactured with a 77 percent NG casting solvent. In order to obtain lead time, the surveillance samples were manufactured with an 80 percent NG solvent. The total difference in NG composition of the propellants is approximately 0.80 percent. This small difference in NG content should not affect aging characteristics. Samples of propellant manufactured with 77 percent NG solvent have been placed in storage for backup. The CYH and DDP propellants are used in all stage III configurations established to date.

2. Objective

The Propellant Storage Test Plan is designed to determine the effects of storage on the physical, chemical, stability, and ballistic properties of CYH and DDP propellants under simulated operational environments. Specimens will be tested for tensile strength, percent elongation, modulus of elasticity, hardness, and other properties as outlined by Hercules Powder Co, Bacchus Works (HPC/B) Laboratory Procedures. The data gained from this program will be used to predict the reliability after storage and the length of useful life of the propellant.

B. TEST PLAN ORIENTATION

This study is divided into two parts: (1) Physical properties tests and (2) subscale ballistics tests. A physical property sample of each propellant type will be withdrawn initially and from each storage condition (100° and 60° F) at 1, 2, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36 months. The blocks will be machined into the required test specimens in accordance with SOP's. The forty-pound charge (FPC) subscale units are stored at 100° F with control units at 60° F. The subscale grains are withdrawn every 3 months for a total of 36 months for testing by motor static firing.

C. DETAILED TEST PLAN

1. Acquisition of Samples

a. Physical Properties Samples

The propellant samples required for the physical properties portion of this program are obtained by casting propellant in 5-in.-dia by 60-in.-long cylindrical phenolic beakers. The propellant grain is then cured, cut, and machined into 3- by 3- by 9-in. blocks. The blocks are wrapped in aluminum foil for storage.

b. Forty-Pound Charge Grains

The FPC subscale testing grains, Hercules drawing No. 152-BU-1, for this program are cast from six separate powder lots used for acceptance testing of Minuteman powder. Twelve grains from each powder lot will be stored.

2. Storage

The test samples are stored at HPC/B in Buildings 2169 and 2170, which are maintained at 60° and 100° F, respectively. Fifteen physical properties blocks from each propellant type and six FPC grains from each casting powder lot are stored in each building.

3. Physical Properties Testing

For physical properties testing, a 3- by 3- by 9-in. propellant block will be machined into the required test specimens prior to each 3 mo test period. Tensile specimens are JANAF "dog-bone" modified as shown in Figure A-1. The physical, chemical, and stability properties tests to be conducted are as follows:

Properties	Test Specimen	Bacchus Laboratory Procedure Manual No.
Tensile strength	Dog bones	Section 3, Method 3
Percent elongation	Dog bones	Section 3, Method 3
Modulus of elasticity	Dog bones	Section 3, Method 3
Hardness	Dog bones	Section 3, Method 21
Auto ignition	1-1/4 in. cubes	Section 3, Method 15
Specific gravity	--	Section 2, Method 39
Percent stabilizer	--	Section 2, Method 1
German test	--	Section 3, Method 55
Taliani test	--	Section 3, Method 20

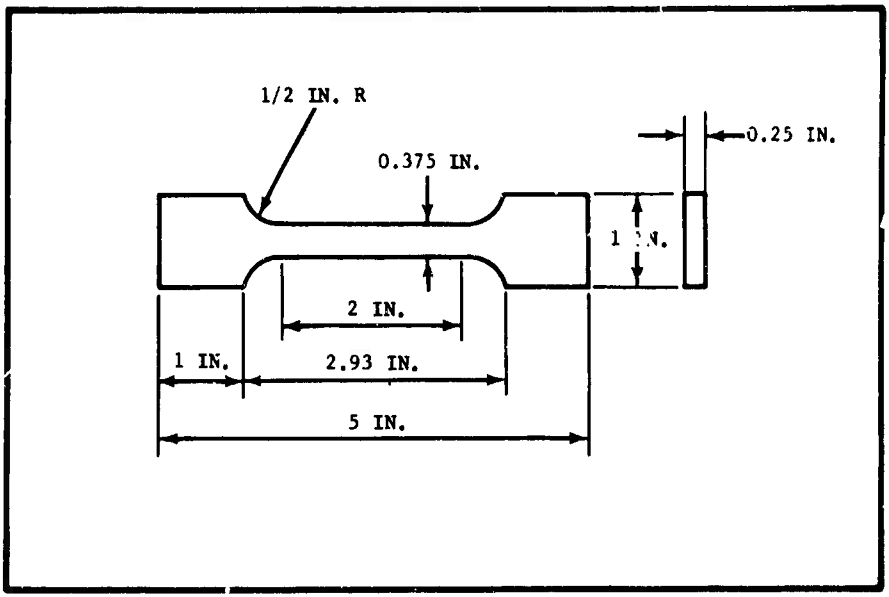

Figure A-1. Propellant Tensile Specimen

4. Testing Forty-Pound Charge Grains

The FPC grains are cast in a triple-length phenolic beaker with a cylindrical core, and then cut to the required length. The middle grains are stored, and the end grains are tested to provide the initial data. The data from the acceptance testing of these powder lots will also serve as initial data for determining the effect of aging on the propellant ballistic properties. After the scheduled storage is completed, the grain is inserted in a steel-cased motor, Hercules drawing No. 183-BU-1 (Figure A-2), and static fired in accordance with Hercules range procedures, at intervals presented in Table A-1A. The following parameters are measured:

(a) Average burning rate

(b) Specific impulse vacuum

(c) Average pressure

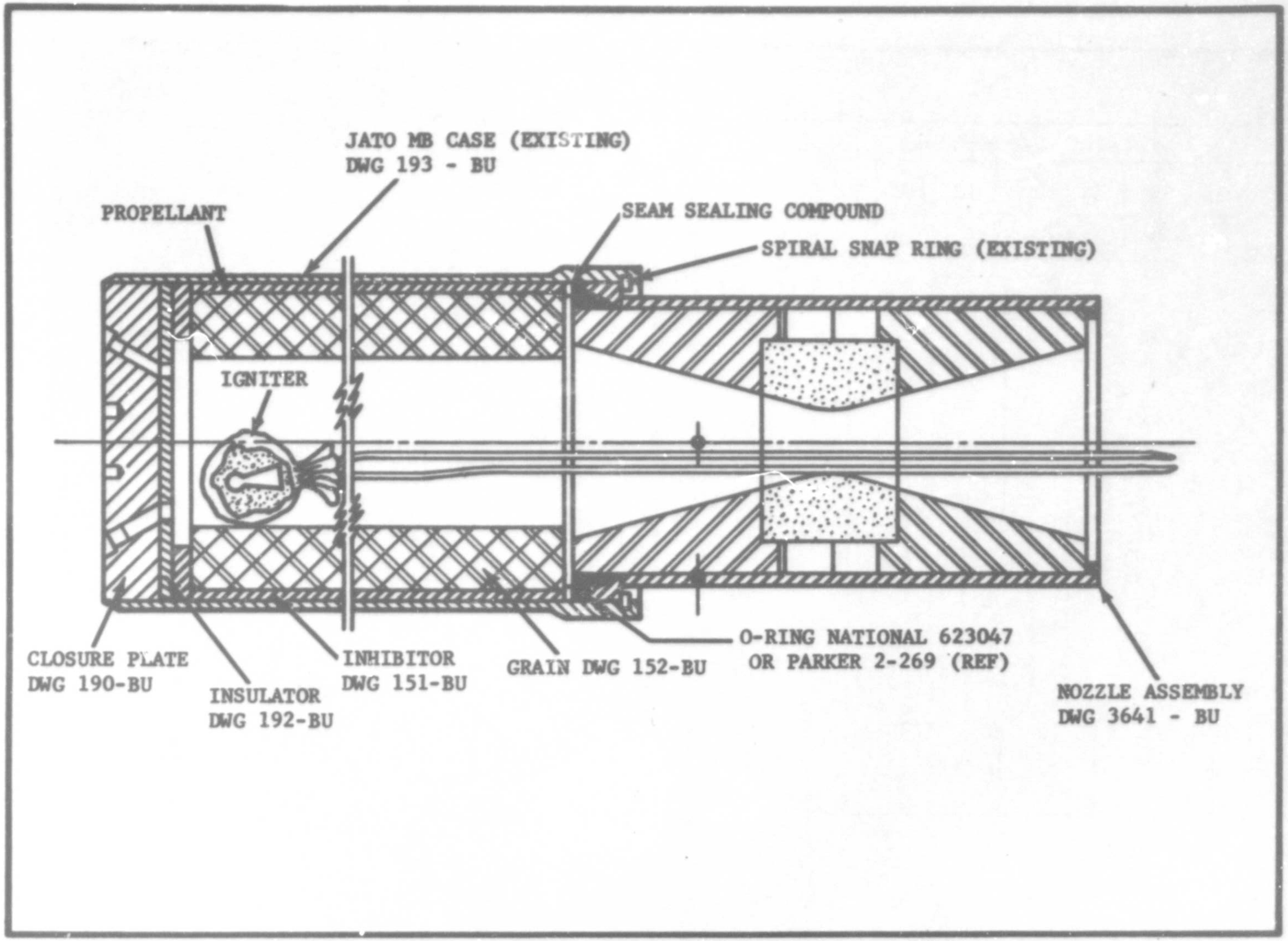

Figure A-2. Forty-Pound Charge Test Motor Assembly

TABLE A-1A

PROPELLANT BALLISTIC TEST SCHEDULE

Powder	Lot	Storage Temp (°F)	Zero Time Date	Test Sequence (mo from zero time) 3	6	9	12	15	18	21	24	27	30	33	36
HDDR-A	86-C	60	Feb 60	1	1	1		1			1				1
		100					1		1	1		1	1	1	
HDDR-A	27-60	60	Mar 60		1	1			1		1			1	1
		100		1			1	1		1		1	1		
2056-D	31-60	60	Apr 60			1		1	1		1			1	1
		100		1	1		1			1		1	1		
CYH	Bacchus 1	60	Apr 60	1	1						1	(1 FPC held for backup)			
		100				1									
HDDR-A	41-60	60	Jun 60				1	1	1	1			1	1	
		100		1	1	1					1	1			1
2056-D	69-B	60	Sep 60	1	1										
		100				1									
HDDR-A	32-60	60	Sep 60	1	1										
		100				1									
2056-D	69-B	60	Oct 60	1		1		1	1						
		100			[illegible]		1	1		1	1				
2056-D	98-A	60	Mar 61	1		1		1		1		1			
		100			1		1		1		1		1	1 (1 FPC held for backup)	

ADDED 1 September 1966

TABLE A-1A (Cont)

PROPELLANT BALLISTIC TEST SCHEDULE

Powder	Lot	Storage Temp (°F)	Zero Time Date	Test Sequence (mo from zero time)											
				3	6	9	12	15	18	21	24	27	30	33	36
HDDR-A	69-A	60	Sep 60	1		1									
		100			1										
HDDR-A	69-A	60	Mar 61	1		1									
		100			1										
HDDR-A	82-60	60	Mar 61	1		1									
		100			1										
DDP	Kenvil 1	60	Apr 61				1			(1 FPC held for backup)					
2056-D	14-61	60	Apr 61	1		1	1	1	1	1					
		100			1						1				
DDP	62-A-61	60	Sep 61						1				1 (1 FPC held for backup)		
		100			1		1				1				
DDP	49-61	60	Sep 61								1		1 (1 FPC held for backup)		
CYH	100-A-61	60	Dec 61									1 (1 FPC held for backup)			
		100				1			1						
CYH	78-61	60	Dec 61				1								
		100									1 (1 FPC held for backup)				
CYH	56-62	60	Aug 62			1									
		100									(2 FPC held for backup)				

Technical Operating Report
B O B Approval No. _______

MOTOR STORAGE STUDIES PROGRAM PLAN

MTO-258-3A, REVISION 2

WEAPON SYSTEMS 133A AND B

15 January 1966
Changed 1 July 1966

Volume II

Contract Number AF 04(694)-544

LATEST CHANGED PAGES SUPERSEDE
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Insert changed pages. Destroy superseded pages.

Prepared by

HERCULES INCORPORATED
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
Norton Air Force Base
California

LIST OF EFFECTIVE PAGES (Volume II) 1 July 1966

The effectivity of the pages listed below are indicated by the issue date. Insert latest changed pages and destroy superseded pages. The portion of text affected by the changes is indicated by a vertical line in the left-hand margin of the changed page.

Page No.	Issue
*Title	1 Jul 66
*A	1 Jul 66
*i thru vii	1 Jul 66
3-1 thru 3-31	Original
*3-32	1 Jul 66
3-33 and 3-34	Original
*3-35	1 Jul 66
3-36	Original
*3-37 thru 3-40	1 Jul 66
*3-41 Added	1 Jul 66
*3-42 Blank	1 Jul 66
A-1 thru A-7	Original
4-8 Blank	Original
4-9 thru A-17	Original
A-18 Blank	Original
A-19 thru A-21	Original
A-22 Blank	Original
A-23 thru A-37	Original
A-38 Blank	Original
*B-1	1 Jul 66
B-2 thru B-10	Original
C-1 thru C-7	Original
C-8 Blank	Original
D-1 thru D-4	Original

Report No. MTO-258-3A, Rev 2, Change 1

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Date 1 July 1966

MOTOR STORAGE STUDIES PROGRAM PLAN
WEAPON SYSTEMS 133A and B

Volume II

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FOREWORD

This document presents the Motor Storage Studies Program Plan and the Hercules plan for development of failure criteria.

The original authority and requirements for motor storage studies were established in Contract AF 04(647)-243, Exhibit B, paragraph III.F.5, and Exhibit D, Section III, paragraph D.9; and as amended by CCN's No. 108, 165, and 200.

Authority for continuation of the motor storage program from 1 July 1963 thru 30 June 1965 is given in Contract AF 04(694)-127, Exhibit A, paragraph D.9, as amended by CCN No. 50.

This document supersedes MTO-258-3A, Revision 1, Motor Storage Studies Program Plan, dated 1 December 1964, and is presented in two volumes. Volume I contains the effort which was transferred from Air Force Systems Command (AFSC) to Air Force Logistics Command (AFLC) in the transfer of engineering responsibility of Wing I thru Wing V. Each test schedule indicates the effort remaining as of transfer date, 1 October 1966.

Volume II contains the effort for full-scale units and materials unique to Operational Reliability Improvement (OPRI), which is the responsibility of AFSC.

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Magna, Utah

ABSTRACT

The Minuteman stage III motor storage studies are comprised of three major tasks: Motor Storage, Laboratory Support, and Failure Criteria Development. The program plan since initiation in 1958 has been continually updated for AFBSD. In December 1965 Hercules received contractual coverage to divide the program plan into two volumes, one volume to contain the effort for which the engineering responsibility is to be transferred from AFSC to AFLC (Wings I through V motors and components), and the other volume to contain the effort for which the engineering responsibility will remain with AFSC after 1 July 1966.

1. Volume I

Volume I of this document contains the history of the overall program and the effort required after transfer of engineering responsibilities to AFLC. This volume contains the AFLC portion of the storage program plan including the areas described in the following paragraphs.

Wings I through V motor storage is primarily designed to demonstrate storage capabilities of the Minuteman stage III rocket motor. To accomplish this, a total of 27 full-scale motors (15 Wing I R & D, 2 Wing I operational, 6 Wing II operational, and 4 Wing IV operational) were placed in storage under simulated operational environments, conditioned, inspected, and static tested after aging periods from 1 to 10 yr.

The Laboratory Support Program (Wings I through V component and material testing) is designed to predict the service life of the individual components and materials and ultimately the service life of the stage III motors. The study involves storing, conditioning, and testing components and materials used in the stage III motors, independent of the motors. These components and materials are stored under environments representing the common and extremes of the Minuteman Model Specification. Resultant test data are analyzed and compared to previous test results to establish the aging trends used for service life prediction as reported quarterly.

The Failure Criteria Development Program has been added to the original scope of the program to provide failure criteria for items tested in the Laboratory Support Program. This criteria is essential for making accurate and meaningful service life predictions.

2. Volume II

Volume II of this document contains the effort for which AFBSD will retain the engineering responsibility after 1 July 1966. This effort contains two Wing VI full-scale motors and Wing VI unique materials and components. The storage conditioning and testing of these items is performed in a similar manner to those items being tested in Volume I.

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LIST OF FIGURES

CHANGED 1 July 1966

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SECTION II

OPERATIONAL RELIABILITY IMPROVEMENT, PROPELLANT-TO-LINER BOND SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

The propellant-to-liner bond in the stage III Minuteman motor is achieved by embedding particles of base grain in semicurred epoxy which has been sprayed on the internal case insulation. An intermediate layer of epoxy is sprayed and cured intially to serve as an NG barrier.

The case-bond systems referred to in this test plan (Table 3-7) consist of the rubber liner, barrier coat, embedment coat, base grain, and propellant. The systems for Operational Reliability Improvement (OPRI) are No. 19 and 22. Systems No. 15, 17, 18, and 21 were candidate OPRI systems and are now being held for backup only.

The various sample sizes and preparation methods described in this test plan reflect improvements made to the case-bond testing. Improved specimens, methods of preparation, and testing have been included in the storage program as new case-bond systems are incorporated into the stage III motor.

Systems 15, 17, and 18 utilized tensile specimens prepared from a 1.128- in.-dia steel plate on which the rubber, epoxies, and embedment are placed. After embedment, the plates are cast into 3-1/2 in. sq. cellulose acetate (CA) beakers. Samples for systems 19, 21, and 22 were prepared, using the Refractory Index (RI) embedment technique, from embedded liners removed from PQC cases. Process control information of these systems is given in Table 3-8. For system 19, the embedded rubber is bonded to the round plates and cast in physical test beakers. This method of preparing samples more closely simulates actual stage III motor processing. The peel specimens for systems 21 and 22 were prepared in the same manner as the tensile specimens.

As a means of verifying the results obtained from laboratory prepared samples, tests will be conducted on peel and tensile specimens obtained by dissection of aged Wings I and II motors.

B. DETAILED TEST PLAN

1. Sample Acquisition and Preparation

a. Tensile Specimen, Systems 15, 17, and 18

The case bond tensile specimens shown in Figure 2-11 were prepared at Bacchus as follows:

(1) The metal plates were grit blasted to facilitate bonding.

(2) The plate and rubber liner were cleaned with Tri-clean solvent.

TABLE 3-7

PROPELLANT-TO-LINER BONDING SYSTEMS

System No.	Applicable Motor Configuration	Bonding System and Barrier Coat	Embedment Grain	Propellant	Case Bond Lacquer	Test Specimen Description
15*	None	Epon 923/SBR rubber	CYH	CYH	None	Round plate
17*	None	Epon 923/SBR rubber	CYH	CYH	None	Round plate
18*	None	Epon 923/SBR rubber	CYH	DDP	None	Round plate
19	Wing VI OPRI	Epon 923.2/SBR rubber	CYH	CYH	None	Round plate
21*	None	Epon 923/SBR rubber	CYH	CYH	None	Peel
22	Wing VI OPRI	Epon 923.2/SBR rubber	CYH	CYH	None	Peel

*Held for backup only

TABLE 3-9

CASE-BOND TEST SCHEDULE

System No.	Test Performed	Storage Temp (°F)	Zero Time Date*	Test Sequence (mo from zero time)																								
				0	3	6	9	12	15	18	21	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
15	Tensile	60	Jul 62	8**						8		8			8													
		100	Jul 62	8	8	8	8	8	8	8	8	8	8	8		8 specimens held for backup												
17	Tensile	100	May 63	8	8	8	8	8		8						72	11			11	11	11		11				
18	Tensile	100	May 63	8	8	8	8	8		8						72	11			11	11	11		11				
19	Tensile & Chemical	60	Aug 64						8	8	8	8	8	8	8	8	8	8	8									
		100	Aug 64						8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
21	Peel	60	Mar 66	3		63 specimens held for backup																						
		100	Mar 66	3	72		11				11	11		11	11													
22	Peel & Chemical	60	Mar 66	3		3		3		3		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		100	Mar 66	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

*Zero time is fabrication date

**Number of specimens tested

c. Peel Strength

The 90° peel test will be conducted in accordance with Bacchus Laboratory Procedure, Section III, Method 57. The peel specimens will be tested in accordance with the schedule in Table 3-9.

The Case Bond Failure Criteria Study presented in Chapter 2, Section XIV should provide the required test improvements and corresponding failure criteria.

Until the improved tests and failure criteria can be obtained, the evaluation of case-bond data will be limited to the present trend analysis to verify that degradation does not occur.

SECTION III

OPERATIONAL RELIABILITY IMPROVEMENT, ADHESIVE AND POTTING COMPOUND SERVICE LIFE PREDICTION STUDY

A. INTRODUCTION

This study includes the following types of adhesive in combination with potting compounds and propellant to be studied as candidate materials for Wing VI: (1) Adhesive conforming to specification HPC-133-08-7-56, Type III (948.2/953), used to bond boot to flap; (2) rubber cement conforming to specification HPC-133-08-10-14 (SBR/Skellysolve-B), used to bond boot to flap prior to vulcanizing; and (3) adhesive conforming to specification HPC-133-08-7-31, composition (Epon 923.2) used as case-bond powder embedment bonding agent.

Potting compound BPC No. 2 will be used around the nozzle-to-propellant interface.

B. DETAILED TEST PLAN

The types of specimens to be used and the quantity of each are as contained in Table 3-10. Specimen configuration was chosen to simulate suspected modes of failure for each adhesive being studied. Testing will be conducted as indicated in Tables 3-11 and 3-12.

1. Preparation of Specimens

a. Boot-to-Flap Peel

Metal plates will be cut to 10- x 5- x 1/2-in. size, and rubber sections will be cut to 6- x 4-in. size prior to vulcanizing. Rubber sections will be cut to 6 x 3-1/4 in. size following the vulcanizing sequence. Following the bonding of these components, a 1/4-in.-wide groove will be cut in the rubber sections, leaving three 1-in.-wide rubber strips on each plate. (Samples will have the same basic configuration as shown in Figure 2-34 with the following modifications: Rubber strips will be 1- x 6-in. size, no potting compound will be used, and propellant sections will be eliminated.) The procedure is as follows:

(1) Rubber is cut to 4- x 6-in. sections.

(2) The 4- x 6-in. boot and flap rubber sections are sanded.

(3) One boot and one flap-type rubber section are vulcanized together leaving a 1-in. flap along one 4-in. side. (Teflon tape is used as a barrier for the 1-in. flap section.)

(4) Metal plates are sand blasted and degreased.

TABLE 3-10

ADHESIVE AND POTTING COMPOUND
MATERIALS AND TEST DESCRIPTION

Material	Type of Test	Type of Sample*	Original Quantity
Epon 948.2/953	Tensile	JANAF	96
	Lap shear	Al/Al	96
	Lap shear	Al/SBR/Al - BPC-2/CYH	264
	Peel	SBR/SBR - BPC-2/CYH	264
Epon 923.2	Lap shear	Al/NBR/Al - BPC-1/CYH	120
	Lap shear	Al/SBR/Al - BPC-1/CYH	120
	Peel	NBR/NBR - BPC-1/CYH	120
	Peel	SBR/SBR - BPC-1/CYH	120
BPC-2	Chemical analysis and compatibility	Compatibility and B-1 fix configuration	8

*Type of Sample - JANAF (See Figure 2-32), Lap Shear (See Figure 2-32), Peel (See Figure 2-34), Compatibility (See Figures 2-35 and 2-36), B-1 Fix (See Figure 2-33)

Al - Aluminum, NBR - Buna-N Rubber, SBR - Buna-S Rubber, BPC - Bacchus Potting Compound, CYH - Propellant

TABLE 3-11

POTTING COMPOUND TEST SCHEDULE

Material	Test	Fabrication Date	Store Temp (°F)	Test Sequence (mo from zero time)*										
				0	6	12	18	24	30	36	42	48	54	60
B-1 fix	Visual	Nov 65	100	a	a	a	a	a	a	a	a	a	a	a
	Control	Nov 65	100	a	b	b	b	b	b	b	b	b	b	b
Bacchus potting compound No. 2	Visual	Nov 65	60	a	a	a	a	a	a	a	a	a	a	a
	Control	Nov 65	60	a	b	b	b	b	b	b	b	b	b	b

*Test Sequence:

a = Inspect and photograph

b = Remove from storage, inspect, vibrate, and photograph

TABLE 3-12

ADHESIVE COMPOUND TEST SCHEDULE

Materials[a]	Test	Zero Time Date[b]	Store Temp (°F)	Test Sequence (mo from zero time)															
				0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
Epon 948.2/953	Tensile[c]	Mar 66	100	4[d]	4	4	4	4	4	4	4	4	4	4					
	Tensile	Mar 66	80	4		4		4		4		4		4	4	4	4	4	4
Epon 948.2/953	Lap shear	Mar 66	100	4	4	4	4	4	4	4	4	4	4	4					
			80	4		4		4		4		4		4	4	4	4	4	4
Epon 948.2/SBR																			
(Plain)	Lap shear	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(Plain)	Lap shear	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(BPC No. 2)	Lap shear	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(BPC No. 2)	Lap shear	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(Plain)	Peel	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(Plain)	Peel	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
(BPC No. 2)	Peel	Mar 66	100	6	6	6	6	6	6	6	6	6	6	6					
(BPC No. 2)	Peel	Mar 66	60	6		6		6		6		6		6	6	6	6	6	6
Boot-to-flap	Peel	Aug 66	100	6	6	6	6	6	6	6	6	6	6	6					
	Peel	Aug 66	60	6		6		6		6		6		6	6	6	6	6	6

(a), (b), (c), (d) Refer to last page of table for legend

TABLE 3-12 (Cont)

ADHESIVE COMPOUND TEST SCHEDULE

Materials[a]	Test	Zero Time Date[b]	Store Temp (°F)	Test Sequence (mo from zero time) 0	6	12	18	24	30	36	42	48	54	60	72	84	96	108	120
Epon																			
923.2/NBR	Lap Shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/NBR	Lap shear	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
923.2/NBR	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/NBR	Peel	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
Epon																			
923.2/SBR	Lap shear	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/SBR	Lap shear	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6
923.2/SBR	Peel	Nov 65	100		6	6	6	6	6	6	6	6	6	6					
923.2/SBR	Peel	Nov 65	60			6	3	3	3	3	3	3	3	3	6	6	6	6	6

[(a)]Material: SBR - Buna-S Rubber, BPC - Bacchus Potting Compound

[(b)]Zero time date is fabrication date

[(c)]Tensile specimens are tested for tensile, elongation, and hardness

[(d)]Numbers of specimens tested

(5) The vulcanized rubber section is cut to a 6- x 3-1/2 in. size.

(6) The 6 x 3-1/2 in. rubber sections are sanded and degreased.

(7) Epon 913 adhesive is mixed.

(8) The rubber sections (boot surface) are bonded to metal plates.

(9) Epon 913 adhesive is cured for 8 hours at 80° F.

(10) Epon 923.2 adhesive is mixed.

(11) Cloth backing is bonded to the rubber sections (flap surface).

(12) Epon 923.2 is cured for 16 hours at 120° F.

(13) A groove is machined in the rubber, forming 1- x 6-in. specimens.

(14) Samples are wrapped with polyethylene.

(15) Samples are marked with type of sample and date.

(16) Wrapped samples are placed in proper storage environment.

b. Lap Shear, Tensile "Dog Bone," B-1 Configuration, and Peel Specimens

The established procedures for preparing lap shear, tensile "dog bone," B-1 fix configuration, and peel samples, as described in Chapter 2, Section XIII, will be applicable for OPRI Wing VI adhesives and potting compounds with the following changes incorporated: The adhesive to be tested will be Epon 948.2/953, and the potting compound will be Bacchus Potting Compound No. 2.

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APPENDIX B

FULL SCALE MINUTEMAN GRAIN DISSECTION PROCEDURE

A. INTRODUCTION

Hercules Incorporated, Bacchus Works (Hercules/B) Minuteman Surveillance Program will require dissecting of six full-scale aged grains and periodic testing as indicated in Table 1-3; five Wing I and one Wing II motors will be dissected. The cuts to be made are as shown in Figures B-1 through B-8. Hercules/B will machine the samples to specimen configuration just prior to testing.

B. METHOD OF DISSECTION

1. Grain Inspection and Marking

Bacchus Works will X-ray each grain for high density inclusions, solvent rich areas, dry powder, and other abnormalities existing in the grain. A second X-ray will be performed, and special shots of this X-ray will be utilized. Each motor will have metal bands and lead tape attached in positions of cuts prior to the second X-ray. The X-ray shots will be taken in positions where cuts are nearest any metal and at case contour changes. The X-ray report, generated from the second X-ray, will document the distances of cuts from any metal hardware and provide case and insulator profiles at the position of each cut.

2. Cutting Sequence

a. Major Cuts

The major cuts will be made starting at the forward dome and progressing to the aft dome. Measurements for the major cuts will be made from the aft skirt. Cuts, measurements, and marking will be as shown in Figure B-1 and as marked on the case.

b. Section Cuts

The grain will be cut as shown in Figures B-1 through B-8. Linear tolerances are ±1/8 in. and angular-tolerances are ±1/2 degree. Sections II and III will be cut into eight pie-shaped segments. All segment cuts will be referenced to a zero degree reference, which will be the center of No. 1 nozzle and No. 1 TT port as marked on the case. The segmenting cuts will be as shown in Figure B-2 for section II and Figure B-6 for section III.

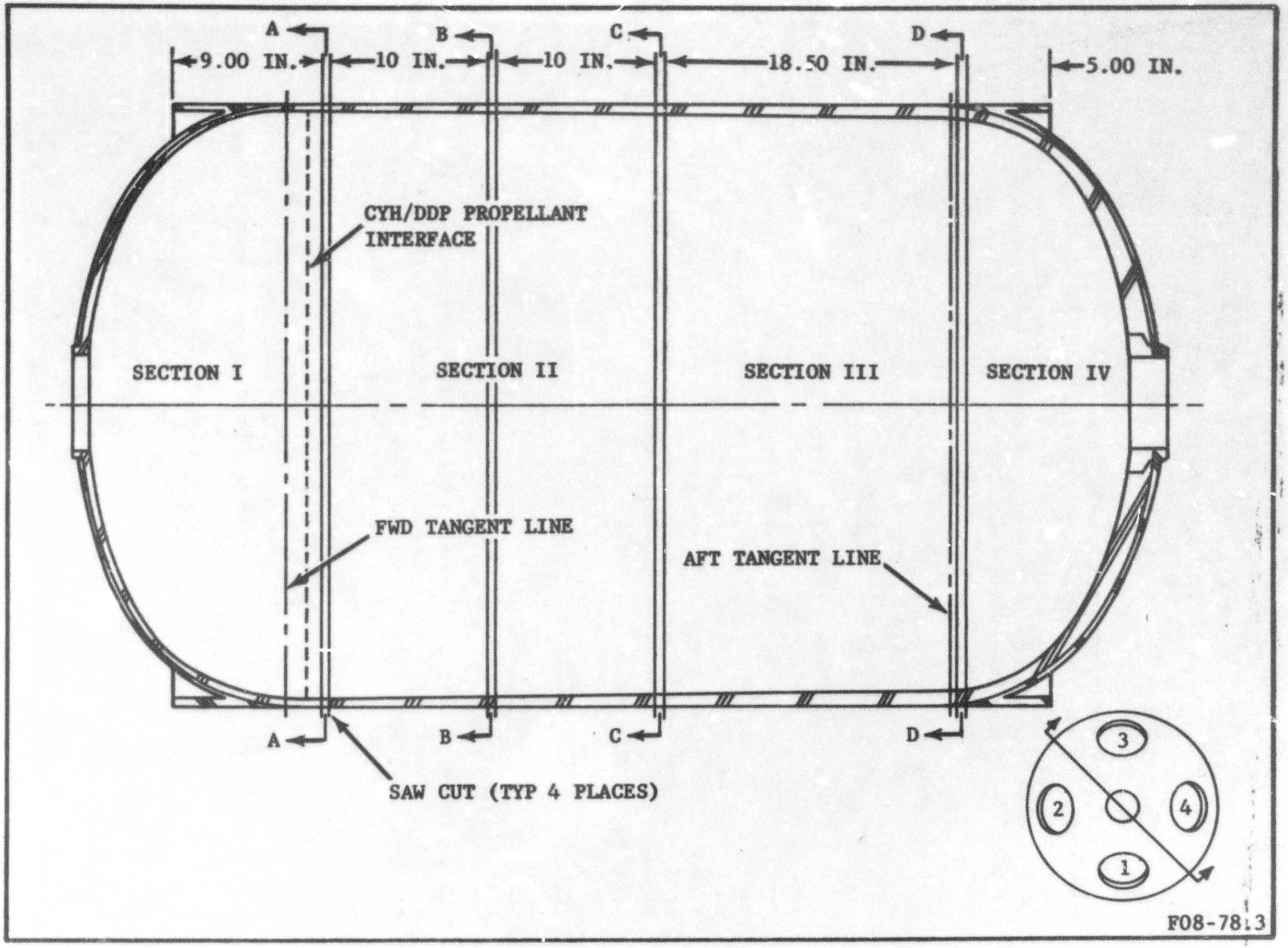

Figure B-1. Case Sections